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THE KOYUKUK-CHANDALAR REGION ALASKA

BY

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PREFACE.

By Alfred H. Brooks.

In 1899 F. C. Schrader and T. G. Gerdine carried a topographic and geologic reconnaissance survey through the Chandalar and Koyukuk basins, in northern Alaska. This was the first investigation of the mineral resources north of the Yukon. The time was well chosen, for it was in 1899 that the first important discoveries of placer gold were made in the Koyukuk district, though there had been some mining on the river bars during the previous decade. Since 1899 the Koyukuk has produced gold to the value of about $2,500,000. Some promising gold-bearing veins have also been found in the Chandalar region.

As this progress in mining gave promise of yielding much new information about the occurrence of mineral deposits, and as Schrader's report had long been out of print, a second investigation of this field seemed justified. This resurvey was made by A. G. Maddren in the course of a single field season, during which he visited practically all the important localities of mining and also considerably extended the areal surveys. Mr. Maddren had the benefit of the geologic results achieved since 1899 in other parts of the Yukon basin, which have helped to elucidate a number of the stratigraphic problems. Although Mr. Maddren's conclusions as regards the geologic sequence differ somewhat from those reached by his predecessor in this field, yet this volume must in a measure be regarded as a revised edition of Schrader's report, which has proved remarkably accurate considering the conditions under which the field investigations were carried out.

Other systematic surveys have recently been made in northern Alaska. In 1911 and 1912 Mr. Maddren carried a geologic survey northward from Porcupine River to the Arctic Ocean, along the international boundary (one hundred and forty-first meridian, west longitude). In 1910 and 1911 P. S. Smith made reconnaissance surveys in the Kobuk and Noatak region, and the results of his work are embodied in a report[1] now in preparation, which will include a

[1] Smith, P. S., The Noatak-Kobuk region, Alaska: Bull. U. S. Geol. Survey No. 536.

geologic map of an area that extends eastward to the western boundary of the area mapped in the present volume (Pl. V, in pocket). These two maps will serve to elucidate the general geologic features of this northern region.

The geology of the northern part of this region has also been investigated. In 1901 F. C. Schrader and W. J. Peters (see p. 10) carried a geologic and topographic survey across the Endicott Mountains from the Koyukuk basin to the Arctic Ocean at the mouth of Colville River. The Arctic slope, east of the Colville, has been under investigation by E. de K. Leffingwell under private auspices since 1906. All these investigations will throw a flood of light on the geology of this most inaccessible part of Alaska.

THE KOYUKUK-CHANDALAR REGION, ALASKA.

By A. G. Maddren.

INTRODUCTION.

The Koyukuk-Chandalar region, as here defined, includes the drainage basins of upper Koyukuk River and of Chandalar River, both tributary to the Yukon from the north. It is blocked out by the Arctic Circle and the sixty-eighth parallel of north latitude and the one hundred and forty-sixth and one hundred and fifty-fourth meridians of west longitude (Pl. I, in pocket). The special purpose of this report, however, is to describe that part of this region in which gold placers have been developed. A general account of the geography and geology of the whole region, so far as the data at hand warrant it, will first be presented to serve as an introduction to the more detailed statements in regard to the Chandalar and Koyukuk placer districts. These districts lie well within the southern ranges of the mountain system that forms the Yukon-Arctic divide across northern Alaska and are noteworthy as constituting one of the most northerly gold-mining regions in the world.

The information at hand has been gathered by members of four different Geological Survey expeditions following routes essentially different though coinciding to a certain extent. The first party to survey any portion of this field was led by F. C. Schrader,[1] who traveled from Fort Yukon up Chandalar River to the headwaters of its chief branch, portaged across the mountains to Robert Creek, the principal source of Bettles River, descended that stream, and ascended Dietrich River, then returned to the mouth of Bettles River and descended the Middle Fork of the Koyukuk and the main Koyukuk to Nulato, on the Yukon. T. G. Gerdine made a topographic reconnaissance map of this route, and a detachment from the main party, under D. C. Witherspoon, portaged from Slate Creek to the South Fork of the Koyukuk and followed the lower half of that river, carrying a survey over the route traversed. During the sum-

[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 441–486.

mer of 1901 Schrader[1] again made geologic observations with another exploratory expedition, which ascended John River, a large northern tributary of the Koyukuk west of the Middle Fork, crossed the Arctic divide, and descended Anaktuvuk and Colville rivers to the Arctic coast. W. J. Peters, topographer, carried a reconnaissance survey along this route. In the same year a party in charge of W. C. Mendenhall[2] and D. L. Reaburn made similar geologic and topographic surveys from Fort Hamlin, on the Yukon, up Dall River, down the Kanuti to the Koyukuk, up the Alatna, and down the Kobuk to Kotzebue Sound.

All three of these parties traveled with canoes along the larger streams, so that their observations were necessarily confined to the valleys and immediately adjacent regions. In the present account free use has been made of the results of these expeditions to supplement those obtained by the writer. A fourth expedition entered this region during the summer of 1909, when the writer with one man and a pack horse traveled overland from Fort Hamlin to the upper part of Dall River, thence northward over the western ridges and slopes of the mountains that form the divide between the eastern tributaries of the Koyukuk and Hodzana River, across Mosquito and South Forks, through Sitkum Pass and down Slate Creek to the settlement of Coldfoot, at its mouth, on the Middle Fork of the Koyukuk. After spending the month of August visiting the principal placer-mining localities tributary to the Middle Fork as far north as Gold Creek and gathering information about the occurrence, distribution, and general development of the gold placers of the Koyukuk district, the party made a hasty visit to the Chandalar district, to the east, early in September, whence it returned to Fort Yukon by way of Chandalar River. The results of this work, so far as it related to the gold placers, have already been published.[3]

As there was no base map of the region lying between the Yukon and Coldfoot along the route traveled, the writer carried a rough plane-table survey across this area, to connect the previous work of Gerdine and Reaburn. The results of this survey, together with valuable information furnished by prospectors met in the course of the journey, have been incorporated with all other available topographic data at hand in the accompanying map (Pl. I, in pocket). This map is printed on the scale of 1:500,000, or approximately 8 miles to the inch, with 500-foot contours. It is based largely on the surveys made by Gerdine and Witherspoon during the expedition of

[1] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper No. 20, 1904.

[2] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: U. S. Geol. Survey Prof. Paper No. 10, 1902.

[3] Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442 1910, pp. 284–315.

1899, with additions from the portions covered by Peters and Reaburn in 1901 and by the writer in 1909, and from information furnished by prospectors about areas that have not been visited by Geological Survey parties. Although far from being accurate throughout, this map at least has the merit of bringing together in graphic form the most reliable information available in regard to the larger topographic features of the region.

As regards the account of the geology here presented, the obligation of the writer to the work of Schrader and Mendenhall, who covered considerable portions of the area here mapped, will be evident to all who refer to their reports on this region.

TOPOGRAPHY.

GENERAL FEATURES.

The Koyukuk-Chandalar region falls within two of the larger physiographic provinces of Alaska. Its northern third lies within the Endicott Mountains, which are usually considered a part of the northwestern extension of the Rocky Mountain system. The rest of the province, comprising two extensive lowlands and a highland area, which includes some mountains, lies within what has usually been termed the central plateau. It should be stated, however, that the dissected-plateau type of topography is hardly characteristic of the entire region here under discussion, but for convenience of description the term now in the literature will be retained.

This region can further be subdivided into four topographic subprovinces—(1) the Yukon Flats, (2) the highland lying between the Chandalar and the Koyukuk, much of which is drained to the south by Dall and Hodzana rivers and which will be called the Hodzana highland, (3) the Koyukuk Flat and Valley, and (4) the Endicott Mountains. (See fig. 1.)

The southern part of the region is drained southward through Chandalar and other rivers which are directly tributary to the Yukon, and the northern part southwestward through streams that are tributary to Koyukuk River. The Koyukuk, in turn, joins the Yukon about 200 miles southwest of the area here under discussion.

RELIEF.

YUKON FLATS.

The southeastern part of the region here described is a part of the extensive basin lowland known as the Yukon Flats. This feature of relief forms an expansion of the Yukon Valley floor, about 200 miles in length from east to west and 40 to 80 miles in width from north to south. Yukon River flows into this basin from the southeast

out of a valley which, in marked contrast to the flats, is comparatively narrow and deep. Above the flats the valley floor is only from 1 to 4 miles wide, and its slopes rise steeply and in many places abruptly to uplands which stand from 1,500 to 3,000 feet above the river. After traversing the Yukon Flats for about 100 miles in a northwesterly direction the river near Fort Yukon makes a bend to the southwest and here is joined by the large Porcupine River from the northeast. It then flows southwestward for about 190 miles by its winding course, or approximately 120 miles by direct distance, and near Fort Hamlin it leaves the flats by a narrow valley. This, like the valley above the flats, is deeply trenched into an upland.

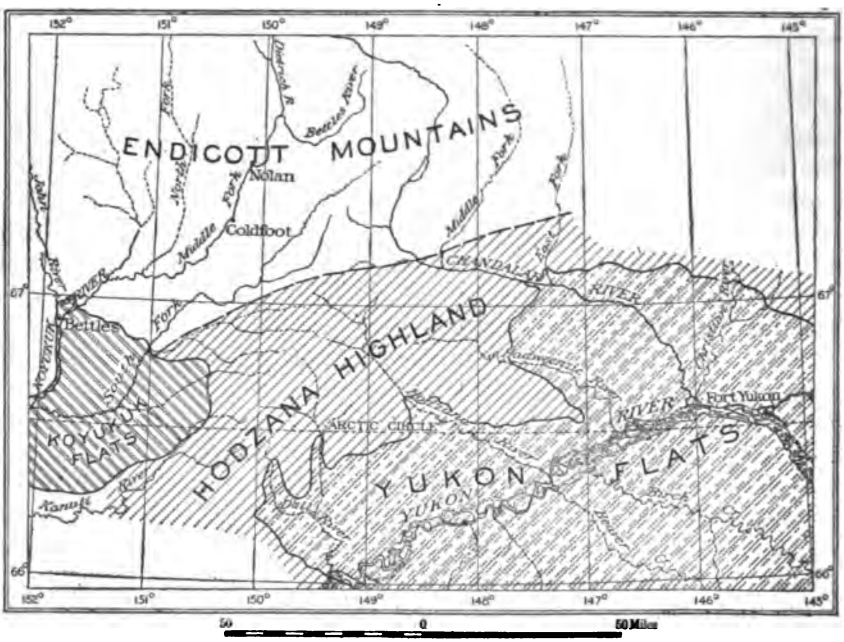


FIGURE 1.—Map showing physiographic provinces of Koyukuk-Chandalar region.

An encircling rim of uplands of varying relief entirely surrounds the Yukon Flats basin, broken only by the upper and lower Yukon Valley as described above and by the valleys of two large tributary streams, Porcupine and Chandalar rivers. These valleys have been clearly incised to their present depth across the upland rim by these streams within a comparatively recent period. In many places gentle slopes rise from the floor of the basin to the higher level of the upland, but here and there the transition is more abrupt, the upland presenting a steep escarpment to the lowland. The Yukon within the flats spreads out broadly and divides into numerous channels that diverge and reunite in a confusing manner about many large and

A. HODZANA HIGHLAND, INCISED BY UPPER VALLEY OF FISH CREEK.

B. MOUNTAINOUS PORTION OF HODZANA HIGHLAND.

Looking south between upper forks of Bonanza Creek.

small islands and bars. This meandering network of channels has in places a width of about 10 miles. The larger islands stand from 8 to 12 feet above the usual river level and are generally thickly timbered with spruce. The lower islands and the bars are more or less covered by the river during flood stages each summer. Where exposed to the rapid currents the banks and bars are being continually eroded away and shifted, but some of them are permanent enough in position to become more or less covered with a good growth of willows. The real banks of the river are usually a few feet higher than the islands. They stand from 15 to 25 feet above the usual river level.

The casual traveler who passes through the Yukon Flats gains the impression that they are actually level. This impression is not quite correct, for the Yukon flows through this basin from east to west for a distance of more than 200 miles with an average current of about 4 miles an hour, and it is evident that the bed of the river has considerable downstream grade. Mendenhall [1] estimates the slope of the Yukon between Fort Yukon and Fort Hamlin to be about 0.9 foot to the mile. Using this estimate, in the absence of definite surveys, as a basis for making an approximate calculation of the grade of the Yukon Flats, we find that the present general surface is about 200 feet higher at the east end of the basin than at the west end.

HODZANA HIGHLAND.

The Hodzana highland embraces a rather ill-defined area bounded on the south and east by the Yukon Flats, on the west by the Koyukuk Flats, and on the north by a broad depression which separates it from the foothills of the Endicott Mountains. This province forms a belt from 40 to 50 miles wide which extends in a northeast-southwest direction in accordance with the trend of the major bedrock structure. The highland is characterized by even-topped ridges from 2,000 to 3,000 feet above sea level (Pl. II, *A*), which have moderately undulating profiles and rounded contours, and above which rise comparatively rugged isolated mountain masses and peaks whose summits stand from 4,000 to 5,000 feet above the sea (Pl. II, *B*).

This highland area is broken into a number of irregularly outlined masses by broad valleys. Some of the mountain masses and peaks which stand above the general level have sufficiently well-defined trends to be classed as minor ranges, and these have received various names, such as the Yukon and Romanzoff mountains. The trend of these ranges is determined by structural features. Their preservation at higher altitudes is probably due to the fact that their constituent

[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 19.

strata are more resistant to weathering than the surrounding rocks. They may, however, be due in part to accidents of erosion. The best defined of these higher masses forms the watershed between the Koyukuk on the west and northwest and the southeastward drainage of the Dall and Hodzana into the Yukon. The general height of this divide is between 3,000 and 3,500 feet above sea level, but some peaks along its crest attain 4,500 to 5,000 feet. The passes along the crest of these mountains range from 1,500 to 3,000 feet above sea level. Some of the mountains along the divide present smooth, rounded profiles; others are much more rugged in form. The rugged forms appear to be caused by the presence of large masses of hard igneous, mainly granitic rocks, dikelike masses of which present serrated forms that stand up prominently on ridges that are otherwise comparatively smooth (Pl. III, *A*).

The depression which bounds the highland area on the north is essentially a broad flat trough bounded for the most part by strong mountain slopes, which trend in an east-west direction. It is about 10 or 15 miles in width and extends from the Koyukuk Valley lowlands on the west to the Chandalar Valley on the east. Its eastward drainage is carried by tributaries of the Chandalar, West Fork, and Crooked Creek, and its westward drainage by the upper South Fork of the Koyukuk and its principal tributary, Mosquito Creek. The divides between these streams are flat and gravel covered, and broad flat-topped ridges at a little higher elevation occupy the interstream areas.

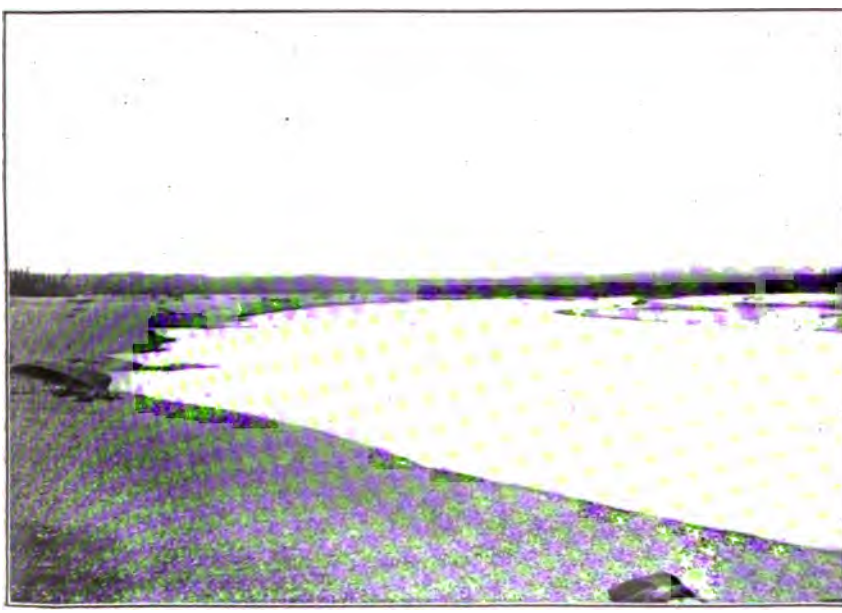
KOYUKUK FLAT AND VALLEY.

The Koyukuk Flat is a broad basin lowland which occupies the southwestern part of the area under discussion. It is bounded on the east and south by the gentle slopes of the Hodzana highland, already described, and on the north by the foothills of the Endicott Mountains (Pl. III, *B*). The bordering slopes in places rise gently or by a series of alluvial terraces. At the mouths of the tributary streams the lowland floor extends up the bottoms of the valleys within the mountains. The lowland is very irregular in outline but is approximately 50 miles square.

This lowland is drained to the southwest, beyond the region here described, by Koyukuk River. The main river hugs the northwest side of the basin and leaves it through a comparatively narrow valley entrenched into a highland which forms its rim in this direction. This valley is comparable in a general way with that of the Yukon below the Yukon Flats, but differs in not being so deeply cut.

Several tributaries of the Koyukuk meander across this lowland in tortuous courses, and oxbow lakes are not uncommon. The entire floor of the basin is covered with alluvial deposits and resembles the

A. WEATHERING AND WIND EROSION OF GRANITE AT HEAD OF DALL RIVER.



B. FLATS ON MIDDLE FORK OF KOYUKUK RIVER.

A. ENDICOTT MOUNTAINS, IN UPPER DIETRICH RIVER VALLEY.

B. RAPIDS ON CHANDALAR RIVER, 128 MILES ABOVE MOUTH.

Yukon Flats, with which it has been compared by Schrader. Mendenhall has noted the southern extension of this broad basin along the lower Kanuti River from 30 to 60 miles above its mouth.

ENDICOTT MOUNTAINS.

That part of the region lying north of latitude 67° lies chiefly within the belt of rough topography which has been called the Endicott Mountains (Pl. IV, *A*). These mountains embrace a rugged mass whose crest line is north of the region here described. They are, however, a part of the mountain system which stretches for more than 400 miles westward from the international boundary (141st meridian, west longitude) and forms the watershed between the Yukon drainage on the south and the streams that discharge into the Arctic Ocean on the north. In their widest place the mountains are about 80 miles in width. They are broken by broad passes and dissected by many valleys, which have been deeply glaciated. On the north they fall off abruptly to a region of less relief, the broad interstream areas of which form the Anaktuvuk Plateau, but on the south they descend to the Koyukuk and Chandalar valleys through a series of deeply dissected foothills. The highest peaks vary in altitude from 7,000 to 9,000 feet, but the average altitude of the crest line is only about 6,000 feet above the sea. Schrader has noted what appeared to him to be a rather striking accordance of summit level throughout these mountains, but this interpretation is not concurrent with the opinion of the writer. They appear rather a deeply dissected, broad mountainous belt whose topography has been greatly influenced by glacial erosion. The part of the range included in the region here under discussion embraces a series of north-south interstream areas or spurs which are offshoots from the main range, with some isolated peaks of greater relief to the north and more or less detached groups of lower mountains or foothills along their southern border.

DRAINAGE.

STREAMS FLOWING SOUTHWARD TO THE YUKON.

GENERAL FEATURES.

The general character of that part of Yukon River embraced within the area shown on the map (Pl. I, in pocket) has already been described. Four rivers of considerable size enter the Yukon from the northwest within the Yukon Flats. They are, in downstream order, the Chandalar, the largest, which joins the Yukon 24 miles below Fort Yukon; the Orenzik, about 25 miles below the Chandalar; the Hodzana, about the same distance below the Orenzik; and the Dall, at the west end of the Yukon Flats, 9 miles above Fort Hamlin. All

these streams have similar features. They are more or less parallel, and, after flowing in courses which are upstream in direction as compared with the Yukon, make downstream or right-hand bends as they approach the main river. At their mouths are broad valleys whose floors merge with the Yukon Flats and which narrow upstream. The Chandalar presents some exceptional features, and for this reason and because its drainage basin is of greater present economic importance, it will be described at some length.

CHANDALAR RIVER AND TRIBUTARIES.

The Chandalar River basin drains nearly all the northeast quarter of the area shown on the map (Pl. I, in pocket). It differs from the other three rivers which flow into the Yukon Flats from the northwest in that it rises much farther to the north and northwest, on the Yukon-Arctic divide, in the part of the high and rugged Endicott Mountains which extends eastward from the headwaters of the Middle Fork of the Koyukuk. It has three headwater branches—the East, Middle, and North forks—all of which rise on this divide and flow southward in relatively narrow, deep valleys for about 75 miles in direct distance, through the southern ranges and across the general trend of the Endicott Mountains. The Chandalar has been ascended by small steamers as far as Chandalar station, about 70 miles from the mouth, or 5 miles above its junction with the East Fork.

The westernmost branch, which may properly be considered the upper part of the main river, but is locally called the North Fork by prospectors, is bounded on both its east and west sides by rugged mountains that rise boldly and in many places abruptly from its valley floor to heights of 2,000 to 4,000 feet above the river, or from 3,000 to 6,000 feet above sea level. Along the divide west of this valley some peaks rise to nearly 7,000 feet above sea level. The divides on either side of the North Fork do not lie more than 10 or 12 miles back from the river, so its valley is in few places more than 25 miles wide from one crest to the other. In consequence of this narrowness the lateral tributary drainage is carried mostly by short, swift streams that have steep gulch valleys. The North Fork valley may be considered to end at the southern edge of the Endicott Mountains, just above the point where Crooked Creek comes in from the west and the river turns southeastward. The floor of the North Fork valley is from 1 to 2 miles wide. On the whole it is a filled valley floor like those of all the larger valleys across the southern flanks of the Endicott Mountains, but it presents three features that distinguish it from most of the others. These features are (1) rapids caused by the outcrop of bedrock at the river level, about 7 miles above Crooked Creek (Pl. IV, *B*); (2) a large lake 8 miles

long by 1¼ miles wide, which occupies nearly the entire width of the valley bottom and whose lower end is about 8 miles above the rapids; and (3) about 30 miles of silt flats above Chandalar Lake, through which the river flows with a slow current by a winding course. The lake and the silt flats above it are apparently closely related phases of a partly filled bedrock valley, which seems to be a long overdeepened trough whose lower 8 miles is now occupied by Chandalar Lake and whose upper 30 miles is filled by sediments. Chandalar Lake is approximately 2,000 feet above sea level. The character of the sedimentation appears to indicate that formerly the lake extended farther upstream and that it has been and is still being gradually filled at its upper end. Around its shores there are gravel and silt benches which indicate that its surface has been at least from 50 to 100 feet higher and that its lower end was farther down the valley toward the rapids, for the river between the lake and the rapids is now entrenched into silts and gravels in a way that shows that the surface of the lake has been lowered recently. Schrader[1] has suggested that the bedrock basin of this lake is due to glacial erosion.

From the foot of the lake to the rapids, a distance of about 8 miles, the grade and current of the river are moderate. It meanders somewhat and cuts a few silt and gravel banks that stand from 15 to 30 feet high. It runs over some gravel and a few bowlder riffles, and as it approaches the rapids the bowlder riffles become more numerous. At the rapids hard quartzose mica schist crosses the bed of the channel and crops out along the banks (Pl. IV, *B*). Here the bowlders are very numerous, and they continue so to Crooked Creek and beyond around the big eastward bend for a distance of more than 25 miles. This portion of the river has a steeper grade than any other part of its course, and the channel is so thickly strewn with bowlders and cobbles that it is very rough. The current is swift, and there are numerous riffles caused by bowlder and cobble bars.

The Middle Fork of the Chandalar is from 15 to 20 miles east of and roughly parallel to the North Fork. The upper half of its valley is in the rugged divide section of the Endicott Mountains; the lower half is of more open form, and the bordering mountains are not so high as those to the north and west. This open part of the valley is filled with gravel deposits that lie along its sides as terraces or benches. The stream, which is of good size, flows with a moderately swift current through these deposits and in cutting its channel down into them has concentrated the bowlders, cobbles, and coarse gravels along its bed in a series of successive steplike

[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 465.

fans over which the stream flows alternately by steep, short stretches with swift riffles, separated by flatter and longer stretches where the velocity of the current is moderate. In these slack stretches the stream generally flows over finer gravels, sands, and locally over silts. This steplike arrangement of the bars along the Middle Fork of the Chandalar does not seem to have any relation to the form of the bedrock floor of the valley, which is apparently covered to a considerable depth by the unconsolidated deposits, nor to a previous concentration of the coarser materials in the terrace deposits at positions corresponding to the bars along the present stream channel, for the cobbles and bowlders in the older deposits into which the present stream channel is cut do not appear to have localized distribution such as is shown by the bars along the present river bed. These unconsolidated bowlder-bearing benches may be of direct glacial deposition. They are at least of glacial origin to the extent of being outwash deposits.

Between the lower halves of the North and Middle forks of the Chandalar there are two parallel mountain ridges separated by a narrow north-south valley about 30 miles long that is drained by a good-sized stream named Big Creek. The principal gold-placer deposits of the Chandalar district are situated in the headwater gulches of this creek.

Just north of the high mountains at the head of Big Creek there is a very marked east-west depression that connects the valleys of the North and Middle forks. This depression opens into the North Fork valley about 6 miles above Chandalar Lake and joins the Middle Fork valley about 50 miles above its mouth. It is bounded on the north and south by mountains that rise abruptly 2,500 feet above its bottom. The floor of the depression is from 1 to 1½ miles wide and is covered and apparently filled to a considerable depth by unconsolidated glacial outwash deposits. On the surface of these deposits are a number of small shallow basins occupied by a chain of lakes which receive the lateral drainage of short streams from the mountains on either side. The waters of most of these lakes drain westward into the North Fork by way of Lake Creek, but several of the smaller easternmost ponds find an outlet to the east into Middle Fork by way of Grave Creek. Both Lake and Grave creeks have a fall of 300 or 400 feet in their lengths of 8 and 11 miles, respectively, and the lower halves of their courses are intrenched into the unconsolidated filling of the east-west trough which connects the valleys of North and Middle forks. The principal streams tributary to this valley trough on its south side are Big Squaw and Little Squaw creeks, flowing into Lake Creek, and McClellan Creek, flowing into Grave Creek. These creeks flow down deep gulches on the northern slopes of the mountains at the head of

Big Creek. Similar deep gulches are eroded into the southern slopes of this same mountain group by headwater branches of Big and Tobin creeks. It is in these gulches on the north and south sides of this group that the placer gold of the Chandalar district occurs, and its source is in this mountain mass.

The East Fork of the Chandalar, which was not visited, appears to have a valley with the same features as that of the Middle Fork. The mountains between Middle and East forks are somewhat lower and less rugged in form than those between North and Middle forks. The mountains east of East Fork, separating it from Christian River, are also lower and more rounded in form, and toward the south gradually merge into the foothills on the north side of the Yukon Flats. The pronounced east-west valley trough occupied by Lake and Grave Creeks between North and Middle forks continues eastward from Grave Creek to the East Fork, across the mountains that separate these two large branches of the Chandalar. This portion of the trough is occupied by a chain of lakes of much larger size and at a lower level than those between the North and Middle forks.

The courses of the three headwater branches of the Chandalar—the North, Middle, and East forks—are all transverse to the general east-west trend of the Endicott Mountains. The valleys of these streams are comparatively narrow and deep, and bold mountains rise between them to heights from 2,000 to 5,000 feet above their floors. To the south these three valleys open out and join a wide east-west topographic depression that marks the southern border of the Endicott Mountains between Chandalar and Koyukuk rivers. This depression, which has already been described (see p. 14), extends westward from the northern edge of the Yukon Flats, a short distance below the mouth of the East Fork of the Chandalar, for about 75 miles across a wide, open divide to the South Fork of the Koyukuk; thence over another low, flat divide to Tramway Bar, on the Middle Fork of the Koyukuk; and down the Middle Fork valley to the mouth of John River, where it merges with the Koyukuk Flat.

The eastern half of this depression, which separates the Endicott Mountains on the north from the Hodzana Highland on the south, is now occupied by the main Chandalar River. The Chandalar may be considered to begin where the North Fork leaves the Endicott Mountains, is joined by Crooked Creek, and turns eastward. From this bend it flows in a direction a little south of east for about 60 miles, leaves the mountains, enters the Yukon Flats, and gradually swings more to the south before it flows into Yukon River about 24 miles below Fort Yukon.

Crooked Creek and West Fork are about 15 and 20 miles long, respectively. Their valleys are wide basins separated by a flat-topped

ridge that stands about 3,000 feet above sea level. From Crooked Creek to the Yukon Flats, a distance of about 60 miles, the Chandalar Valley has a wide, open form and its bordering mountains have comparatively moderate slopes. All the large tributaries of this section of the valley come from the north. Those from the south, which rise opposite the headwaters of the Hodzana and Orenzik, are all small and short, none being over 10 miles long. The bottom of the valley is from 5 to 7 miles wide and is filled with unconsolidated sediments that appear to be glacial outwash deposits of silts, gravels, cobbles, and a considerable number of large bowlders. These deposits are spread across the whole width of the valley and extend along its whole length. They grade without any change in character into the similar deposits that fill the large tributary valleys from the north, and they extend westward up West Fork and Crooked Creek valleys to their heads, 1,000 feet above the main Chandalar Valley, and across the wide divide into the Koyukuk drainage basin, throughout the larger valleys of which they are as widespread as in the Chandalar basin.

The thickness of this valley filling of poorly assorted silts, gravels, cobbles, and bowlders is not known. The present channel of the main Chandalar is more or less intrenched in these deposits, and runs over a bed of the coarser, more concentrated material, which is so distributed as to form numerous riffles of large cobbles and bowlders. Through most of this section the river flows near the base of the slopes of the mountains that bound the south side of the valley, along which it cuts banks 100 feet high in the unconsolidated deposits and here and there cuts bluffs in the hard country rocks, but at no place is it known to flow upon bare bedrock. Where the river swings to its north bank it rarely cuts banks more than 30 feet high, and all of these are in the unconsolidated deposits, which extend to the north for several miles before they reach the slopes of the mountains. It is not known how high up the mountain slopes the unconsolidated deposits extend, but to judge from the high terraces observed along the valley of the Middle Fork, a height of 500 feet above the river does not seem improbable. Many lakes and ponds occur in shallow basins scattered over the flat surface of the valley filling between the river and the mountains to the north.

The Chandalar leaves the mountains a few miles below the mouth of East Fork and flows for about 60 miles across the gradually descending surface of the Yukon Flats to the Yukon. The fall of the river in this distance is about 400 feet, and its current through the upper half of this section is fairly swift, the grade of the stream bed being about 10 feet to the mile, but the fall gradually becomes less as the river approaches the Yukon, probably decreasing to 4 or 5 feet to the mile. In this part of the channel also there are numerous

riffles caused by fan-shaped bars, but the gravels of these bars are smaller and better assorted than are those of the riffles farther upstream, within the mountains. The river is commonly divided by islands and bars into several channels. It cuts banks of light-colored silts from 30 to 100 feet high as it leaves the mountains, but these gradually decrease to heights of 10 to 20 feet and become darker-colored, like the typical alluvium of the lower banks along the Yukon, and the whole country presents the flat, featureless appearance characteristic of the Yukon Flats. While this appearance is that of a level country, it is evident from the grade of the river that these unconsolidated deposits gradually slope from the northern border of the Yukon Flats to the Yukon, with a fall of at least 400 or 500 feet. At the edge of the flats they merge imperceptibly with the coarser unconsolidated filling of the Chandalar Valley, the surface of which at the mouth of the valley stands at about 1,200 feet above sea level, an elevation corresponding in general with that of similar benches of unconsolidated deposits that occur elsewhere about the borders of the Yukon Flats.

The Chandalar enters Yukon River by several diverging channels. About 7 miles from the Yukon a deep sluggish channel enters the river from the east, draining a chain of lakes and ponds, some of which lie only a few hundred feet from the north bank of one of the Yukon channels. There is an easy portage across this short distance from one of the ponds to the Yukon that is used by the natives and prospectors who travel from the Chandalar to Fort Yukon. Christian River, a stream of considerable length, empties into this sluggish channel a few miles east of the Chandalar. It rises in the mountains north of the flats to the east of East Fork and drains a large part of both the mountainous and the flat country between the Chandalar and the Porcupine.

ORENZIK, HODZANA, AND DALL RIVERS.

The basins of Orenzik and Hodzana rivers have not been visited by any of the Geological Survey parties. The representation of their general location and extent on the accompanying map (Pl. I, in pocket) and the description of the country they drain have been compiled from sketches and notes furnished by prospectors.

Orenzik, Hodzana, and Dall rivers drain all the upland southeast of the divide that separates the Chandalar and Koyukuk basins on the north and west from the northwestern part of the Yukon Flats, which lies between Chandalar River and Fort Hamlin. The divide about the headwaters of these basins extends from east to west for about 60 miles between the Chandalar and the northern tributaries of the Orenzik and Hodzana, turns southwestward at the head of the Hodzana, and thence separates the western tributaries of the

Hodzana and Dall from the drainage basins of the South Fork of the Koyukuk and the Kanuti. This divide is at no place more than 75 miles from the Yukon in direct distance, and Hodzana River, the largest of the three streams, is not more than 125 miles long.

The smaller valleys of all the headwater tributaries of these rivers appear to have rather steep grades, in places descending 1,000 feet within less than 10 miles. As a result, the streams are swift and have cut many deep gorges and some canyons along their upper courses. (See Pl. II, *A*, p. 12.) Even where several of these headwater streams have united to form larger branches and the valleys in general widen out with smooth-topped ridges between them, there are many contractions, caused by spurs of bedrock from the higher ridges through which the rivers have eroded gorgelike sections. Thus along these valleys within the mountains more or less widened or basinlike portions alternate with narrower gorgelike stretches. Many of these basin expansions have more or less flat bottoms, formed by fillings of unconsolidated gravels and finer sediments through which the streams in places meander widely with slackened currents. Through the gorges the channels are generally more direct, with swift currents and even with rapids. In other words, the valleys show considerable physical diversity along their courses through the mountainous Hodzana highland. The basins, like all similar topographic features in northern Alaska, whether high in the mountains or at lower levels, are covered with the usual tundra growth, are almost always swampy, and contain numerous lakelets and ponds.

The valleys of the Orenzik, Hodzana, and Dall all open out into the Yukon Flats in a manner similar to that of the Chandalar. The rivers meander back and forth across rather wide alluvial valley floors bounded on either side by the gradually lowering and receding ridges of the mountains that border the northwest side of the basin. The valley bottoms gradually expand and their filling intergrades with the similar deposits of the flats, over which the rivers flow in the lower 30 or 40 miles by very crooked courses. Over this country, which, like all the rest of the flats, is practically devoid of relief except for its gradually rising slope from the Yukon to the hills, are scattered a number of sloughs, ponds, and lakes, many of which appear to occupy parts of old and abandoned courses of the rivers or their tributaries.

KOYUKUK DRAINAGE BASIN.

TRIBUTARY STREAMS.

Koyukuk River is one of the largest tributaries of the Yukon and is about 700 miles in length from its mouth to the head of its Middle Fork. Within the region here discussed, the Koyukuk receives from the north and northwest five important tributaries that drain a large

area of the southern slope of the Endicott Mountains. These are, from east to west, its Middle Fork or chief headwater branch, the North Fork, and Wild, John, and Alatna rivers. All but the extreme northern headwaters of the first four of these tributaries are shown on the map and will be described. Only a few miles of the lower course of the Alatna comes within the area mapped, so it will not be considered. There are also two large eastern branches of the Koyukuk—the South Fork and Kanuti River. The wide basin drained by all these rivers comprises the upper or northeastern half of the Koyukuk Valley, which is practically the area shown on the western half of the map (Pl. I, in pocket).

KANUTI RIVER.

Kanuti River was surveyed in 1901 by the Geological Survey party in charge of W. C. Mendenhall,[1] who describes it as follows:

> The Kanuti River is approximately 200 miles long. * * * It heads in the same mountains [Hodzana highland belt] whose northern slopes are drained by Fish Creek and Jim River, but within a few miles of its source [opposite the west branch of Dall River] it enters a relatively flat basin, 9 or 10 miles long and half as wide, which contains a number of small lakes and ponds although standing at an elevation of between 1,200 and 1,400 feet. This basin, like all similar topographic features in the North, whatever their relation to sea level, is a marsh, covered with the usual tundra growth. At its lower end, in longitude 150° 45′ west, the river enters a restricted valley, so steeply walled in places as to deserve to be called a canyon, and having a maximum depth of 2,000 feet. The gorgelike character prevails for about 30 miles, and through much of this portion the river can scarcely be called navigable, since it is a succession of rapids, and the channel throughout is obstructed by bowlders of all sizes. Below this stretch the valley gradually broadens, and near the camp of July 12 [60 miles from the Koyukuk] is an extensive flat, which is perhaps a part of the broad basin in which the lower portion of the South Fork of the Koyukuk flows.
>
> Within this lower basin the Kanuti River receives a large tributary from the south in the direction of the sources of the Tozi [Tozitna] and Melozi [Melozitna].
>
> About 25 miles above its mouth the river plunges into a second canyon about 10 miles long and 500 feet in depth. This is the most beautiful section of the river; the stream is swift but free from dangerous rapids, and the bluffs of slate and sandstone rise sheer from the water to a height of several hundred feet. Ten miles above the mouth it receives the waters of the Mentanontli, descended by Lieut. Allen in 1885 after his overland journey from the Yukon.
>
> The hills which border this lower section of the Kanuti River and adjacent parts of the Koyukuk are seldom more than 1,500 feet in height, are not excessively steep, and are well timbered.

SOUTH FORK OF THE KOYUKUK AND TRIBUTARIES.

The South Fork of the Koyukuk is one of the largest and longest branches of that river. It rises about 10 miles west of Chandalar

[1] Mendenhall, W. C., A reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, pp. 22–23.

Lake, or just south of the headwaters of Bettles River, and flows southwestward about 175 miles to join the Koyukuk about 480 miles from the Yukon. At its confluence with the main river it is about two-thirds the size of the Koyukuk above that point. Its general course is parallel to that of the Middle Fork, which lies northwest of it. The main channels of the Middle and South forks are nowhere more than 25 miles apart, and at one place a few miles below Tramway Bar on Middle Fork their main channels approach within 7 miles of each other.

The upper 20 miles of the South Fork valley lies within a rugged part of the southern Endicott Mountains just west of Chandalar Lake. The mountains forming the divide about its source stand over 6,000 feet above sea level, or about 4,000 feet above the valley bottom.

Below this headwater section the river flows through a flat basin area about 15 miles long and 5 miles broad that stands about 2,000 feet above sea level and is partly filled with gravels and silt. This basin is part of the pronounced east-west depression which extends from the Chandalar to the Koyukuk (see pp. 14, 19) and which separates the southern flank of the higher Endicott Mountains from the northern slopes and outlying ridges of the lower Hodzana Highland to the south. The river flows through this basin by a winding course, and on both sides of it there are a number of lakes and ponds scattered over the valley floor. At its northeast corner a broad gravel and silt ridge, whose wide, flat top is only a few hundred feet above the South Fork, or about 2,350 feet above sea level, passes over to the head of Crooked Creek, the tributary of the Chandalar that drains the northern part of the depression already described. The gravel and silt deposits of the basin are continuous with those along the valley of Crooked Creek. A similar but narrower gravel and silt divide passes from this basin westward to the valley of Slate Creek at approximately the same elevation (2,350 feet) as the divide to Crooked Creek, and the deposits of gravel and silt continue down the valley of Slate Creek to the Middle Fork of the Koyukuk. The stream that drains eastward into South Fork from the Slate Creek pass is named Bowlder Creek because of the continuous bed of bowlders it has concentrated from the unconsolidated deposits through which it has eroded its course.

The South Fork flows from the lower or southeast end of this basin by way of a mountain gorge about 7 miles long. The mountains on either side are about 3,500 feet high, or 2,000 feet above the river. Southeast of this mountain section the river again enters the Koyukuk-Chandalar depression, already described. Here the river has intrenched its channel to a depth of about 100 feet for about 5 miles directly southward across these unconsolidated deposits,

beyond which it is joined by Mosquito Creek, a large tributary from the east.

Mosquito Creek has one of its two sources between South Fork and the head of Crooked Creek, in a shallow basin of the same unconsolidated sediments that are so widespread over this depression. Like most of these basins it contains a number of small lakes and ponds. This branch flows southward for about 10 miles through the basin and is then joined by another branch from the southeast which is opposite the West Fork of the Chandalar and whose sources drain a part of the northern portion of the Hodzana highland. The wide pass between the West Fork of the Chandalar and this branch of Mosquito Creek stands at a little more than 2,500 feet above sea level, and a mantle of unconsolidated water-washed sediments appears to extend across it from one basin to the other. From the junction of these two upper branches of Mosquito Creek the main stream flows southeastward for about 15 miles to join South Fork, as already noted. Throughout this distance it is intrenched to an average depth of at least 100 feet into the more or less assorted outwash deposits of gravel, bowlders, and silts that fill practically all the wide depression between the Chandalar and Koyukuk below the level of 2,500 feet. Between the South Fork and Mosquito Creek is a bench of these unconsolidated deposits whose flat surface rises gradually from an elevation of 1,500 feet along the South Fork to 2,000 feet at the southeast end of a narrow mountain ridge 5 miles to the northeast. There are several good-sized lakes on this bench toward the mountains. The narrow ridge extends northeastward for about 15 miles between the upper South Fork and Mosquito Creek basins. Several peaks on its southeast end rise to about 4,000 feet, but its height decreases toward the northeast to low knolls between 2,500 and 3,000 feet high that correspond in appearance and elevation to the similar knolls and wide flat ridges of bedrock between Crooked Creek and the West Fork of Chandalar River.

From the confluence of the South Fork and Mosquito Creek the enlarged river flows to the southwest between the northwestern front of the Hodzana highland and the southern margin of the unconsolidated deposits for a distance of about 25 miles, swinging to the northwest in the lower third of this section and then turning at right angles to the southeast again before flowing through another mountain-gorge section for 20 miles. The mountains of this section rise about 3,000 feet above sea level, or from 1,500 to 2,000 feet above the river.

After passing through this last group of mountains the South Fork is joined from the northeast by another large tributary named Jim River. From this point to its confluence with the main Koyu-

kuk it flows with a crooked course for 65 miles through the flats. About halfway between Jim River and its mouth the South Fork is joined from the east by a third large tributary, Fish Creek.

All the large tributaries of South Fork enter it from the east, Jim River and Fish Creek being the largest. On the divide between these streams and Dall and Hodzana rivers the passes from one drainage basin to the other are from 2,500 to 3,500 feet above sea level. The headwater streams of all these rivers have eroded deep, narrow valleys to a depth of 500 feet or more, below the general level of the Hodzana highland. The interstream areas between Jim River and Fish Creek have the form of flat, even-topped ridges, which have the appearance of mesas (Pl. II, *A*, p. 12). To the north, however, Jim River drains an area of more rugged mountains, one of the groups which rise above the general level of the Hodzana highland (Pl. II, *B*).

MIDDLE FORK OF THE KOYUKUK AND TRIBUTARIES.

The name Middle Fork is here used to designate that branch of the Koyukuk which is formed by the confluence of Dietrich and Bettles rivers and flows southward and westward about 75 miles to the point where it is joined by the North Fork 37 miles below Coldfoot. Middle Fork is the largest headwater tributary of the Koyukuk, and if Dietrich River is considered the principal source of the Koyukuk, it is in reality the main river. Like the North Fork of the Chandalar, the Middle Fork of the Koyukuk has its source on the Arctic divide far back in the Endicott Mountains, through which it flows southward by way of a deep valley that has a gravel-filled floor from 1 to 2 miles wide with rather abrupt mountain slopes on either side rising to an average height of 3,000 feet above the river. Its gradient is rather uniform, being about 20 feet to the mile from a point far up Dietrich River to Coldfoot, at the mouth of Slate Creek, where the narrow mountain valley widens out and its gravel flood-plain coalesces with the widespread sheet of outwash gravel deposits that are a continuation of those extending from South Fork. Although the Middle Fork runs on bedrock for a short distance at the mouth of Gold Creek, and perhaps at other points above this place, it has no rapids. Its current, however, is strong throughout its course in the Endicott Mountains and it flows over many cobble bars in swift riffles.

As many of the details of the drainage basin of that part of Middle Fork which lies within the Endicott Mountains will be considered in connection with the discussion of the gold-bearing placer deposits (pp. 84–105), it is not necessary to give further attention to this subject here.

From the southern edge of the Endicott Mountains just north of Slate Creek the Middle Fork flows through a region of lower relief,

whose topography is varied by low mountains, wide, flat, gently sloping ridges, and a few areas of basin lowlands. The river turns more to the southwest and flows for about 65 miles through this section of lower relief to John River. Along the lower half of this section the channel is near the northern slopes of a group of mountains that lie between it and the South Fork, or along the southern margin of the gravel outwash fill that extends with an average width of 5 miles from Tramway Bar to the mouth of John River. This outwash deposit is apparently in large part a continuation of the similar deposits that are so widespread between Tramway Bar and South Fork. From John River the Koyukuk turns southward and skirts the low slopes of mountains that lie along its west side to its confluence with the South Fork, a distance of 35 miles. Throughout this north-south part of its course silt flats, 20 miles wide, extend between it and South Fork on the east. The basin occupied by these silt deposits has already been described.

CLIMATE.

The winters in the Koyukuk-Chandalar region are long and severe, the temperature being below zero most of the time. Temperatures of —70° have been reported. The average temperature for the three winter months is about —15° F. and for the three summer months about 55° F. The summers, lasting from about the end of May until the middle of September, are characterized by clear weather with only occasional light showers. Brief records indicate that the total annual precipitation on the Koyukuk is between 11 and 12 inches. It is probable that the precipitation within the high ranges is somewhat greater, but there are no records to substantiate this supposition.

The principal supply of water in this region used in placer mining is derived from snow, but a moderate rainfall during the summer also adds a variable and uncertain amount to the total stream flow. The snowfall over this region is not great in average amount, and it is only the great length of the winter season, from October to April, that enables an average depth of 3 to 4 feet of it to accumulate. Most of the snow melts and passes away during May, when the streams are at their maximum flood stage. The larger streams continue to flow strongly during most of June, after which there is a subsidence with spasmodic increases until colder weather in September changes the precipitation into snow, freezes the higher mountain slopes, and lessens the flow. Early in October the rivers become frozen over, and although there is still some flow of water in all the larger valleys, as is made manifest by frequent outbursts from under the ice, these rarely do more than form temporary local accumulations of ice, which disappear the following May. Sometimes, however, these overflows of water from beneath the ice continue throughout the winter and form considerable masses of flood-plain ice, called

"glaciers" by the miners, which are not entirely removed during the following short summer and become somewhat permanent features.

The rugged topography of this region presents many high, cold sheltered slopes and mountain-surrounded basins in which a considerable part of the snowfall does not melt rapidly, so there is generally a reserve flow of water in all the larger streams throughout the summer, but on the smaller creeks water sometimes becomes too scanty for the effective handling of the gold-bearing gravels, and the miners must depend on uncertain rainfalls, especially during August.

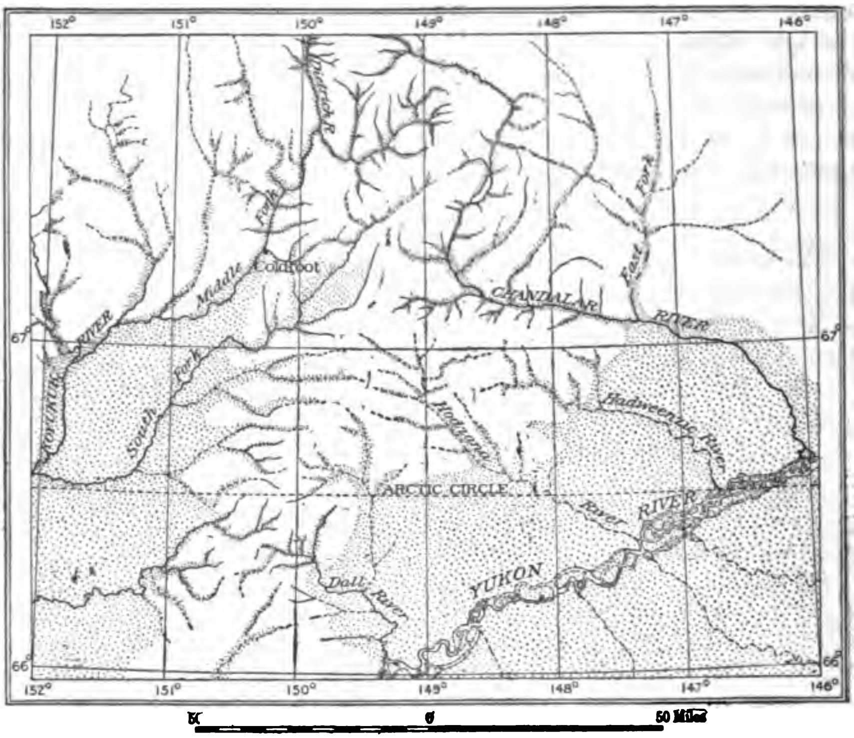


FIGURE 2.—Sketch map showing distribution of timber in Koyukuk-Chandalar region. Dotted areas are timbered.

The short summers, because of the long days, are generally warm enough to allow hardy vegetables to be grown to a good state of maturity in properly prepared gardens in the bottoms of the larger valleys, but killing frosts may occasionally occur in midsummer, even in the most favorable situations.

VEGETATION.

The flats of the Koyukuk-Chandalar region are timbered, and the forest growth extends up the mountain slopes and valleys to an altitude varying from 2,000 to 3,000 feet. A sketch map showing the

distribution of timber is reproduced as figure 2. The timber is largely spruce, but poplar, birch, alder, and willow also occur. Spruce trees as much as 2 feet in diameter are found in the lower courses of some of the larger rivers. This size is exceptional, however, and most of the spruce averages less than 1 foot at the base. Grass suitable for stock is found in some open meadows in the flats and on the uplands above timber line. Moss is the prevailing vegetation at altitudes above 4,000 feet. Of the wild fruits blueberries are the most common, but red currants and cranberries are also found.

ANIMAL LIFE.

Large game is no longer found in the vicinity of the long-established mining camps. The region, as a whole, however, contains moose, caribou, mountain sheep, and bear. Of these the sheep and bear are most abundant. Other mammals in the region include gray wolves, mink, and ground squirrels. Ptarmigan and grouse are abundant in many parts of the region, and in summer geese and ducks are found along the streams and lakes. Salmon run up the Chandalar in summer, but do not reach the lake. Among other fish of the region are trout, grayling, pickerel, and whitefish. The native inhabitants rely on the fish and mammals for a large part of their food supply.

POPULATION AND SETTLEMENTS.

The white population of the Koyukuk region since 1900 has not been large. In the Klondike rush 1,000 or more inexperienced gold seekers entered the Koyukuk Valley in the fall of 1898, but nearly all of them departed during the early summer of 1899 and only about 100 of the more hardy ones remained. Although a revival of interest was caused in 1900 by the discovery of gold on Myrtle Creek and the reports of rich finds on Hammond Creek and the population again reached 1,000 or more, by 1901–2 it had dwindled to about 200. About 350 are reported to have been there in 1903–4, and since then the average population of the district has been about 200 persons. In addition to these there are some natives both in the Chandalar and Koyukuk districts. The census of 1910 gives a total population, both whites and natives, for the entire region, of 823. This, however, includes the settlements on the lower Koyukuk.

Since mining was established in 1900 the principal settlement in the Koyukuk region has been the town of Coldfoot, located on Koyukuk River about 586 miles from the Yukon, at the mouth of Slate Creek. Here the postal and recording offices are established; but about 1908 a new settlement was formed 16 miles farther up the

Koyukuk, at the mouth of Wiseman Creek, and this place is now the largest town in the district.

A small group of cabins on the north bank of Chandalar River near the mouth of Flat Creek is named Caro. This place is about 110 miles from Fort Yukon and 35 miles from the placer diggings at the head of Big Creek. During 1907–8 it had a small population of whites and contained the postal and recording offices for the district. At present only a few natives remain, and the mining population of the district consists of some 20 or 30 white men, including the recording officer for the district, who reside near their claims about the head of Big Creek.

TRANSPORTATION AND TRAILS.

There is only one natural highway for approaching the Koyukuk district—that by way of Koyukuk River. From the middle of June until early in September the main Koyukuk may be ascended by medium-sized stern-wheel steamboats having a draft of about 2 feet. By this means all the supplies for the region are now transported up the river to the vicinity of a warehouse station named Bettles, a few miles below the mouth of John River and about 60 miles below Coldfoot. During some seasons of low water it has been found impracticable to reach Bettles, and at certain periods of high water it is possible for steamboats to ascend a short distance above that place. The general practice is to take all supplies from Bettles, or a point near by, upstream to Coldfoot or the mouth of Wiseman Creek during the summer by shallow-draft scows that carry from 8 to 12 tons, towed by horses (Pl. VIII, *A*, p. 86), or by poling boats that carry about 1 ton, propelled by men. Both methods are tedious and expensive. From June 15 to September 15 may be considered the boating season on the Koyukuk.

Some freight has been hauled in winter on horse or dog sleds up the river from Bettles, and during the earlier years of development this was the common practice. At present this method is used for distributing supplies to the places of mining on the various creeks, supplemented to a small extent by packing with horses during the summer.

The freight charges during recent years have been, from Seattle or San Francisco to Bettles by ocean and river steamboats, 4 to 6 cents a pound; from Bettles to the mouth of Wiseman Creek by horse-towed scows, 6 to 8 cents a pound. Thus, it costs from 10 to 14 cents a pound, or \$200 to \$280 a ton, for freight charges alone from Seattle or San Francisco to the mouth of Wiseman Creek for all the merchandise brought into the Koyukuk district. Winter

sledding of freight from Coldfoot to Nolan Creek is done for 4 cents a pound, and horse packing in summer from the mouth of Wiseman Creek to Nolan Creek for 6 cents a pound.

Practically all the passenger travel to or from the Koyukuk is by boat during the summer, and the heavy mail is also delivered during the open season.

There is also a summer overland route, seldom used, that leaves the west bank of Yukon River a little above and opposite the abandoned trading post called Fort Hamlin and follows the low ridges and benches that form the western border of Dall River valley, crosses the west fork of this river about 45 miles by the trail from the Yukon, goes over the mountains to the north into the headwaters of the south branch of Fish Creek, thence passes over the western ridges and slopes of the moderately high mountains that form the divide between the eastern tributaries of the Koyukuk and the headwaters of the Hodzana, crosses the Mosquito and South forks, and goes through Sitkum Pass and down Slate Creek to Coldfoot. This route is about 150 miles long, but because of the intricate arrangement of the various streams, the roundabout way it follows over the mountains above timber line, and the fact that the so-called trail is recognizable in only a few places below timber line, it is difficult to follow and is suitable only for cattle or packhorse outfits or pedestrians with guides who know the country. (See Pl. I, in pocket.)

To reach this district during the winter or closed season it is necessary to travel with dog-drawn sleds. A monthly winter mail service of this kind is maintained and a few persons occasionally travel in this manner. The present winter mail route goes down Koyukuk River from Coldfoot to the vicinity of Bergman, then across the lower valley of Kanuti River and over the low mountains forming its southern boundary into the upper drainage basin of the Melozitna, thence southeastward across another low mountain divide into the upper valley of Tozitna River and down that valley to the town of Tanana, on the Yukon, where a connection is made with the Yukon-Tanana mail route to Fairbanks. The distance from Coldfoot to Tanana by this route is about 220 miles. Previous to 1906 mail, both in winter and summer, was carried to Coldfoot from Fort Yukon up Chandalar River and its West Fork, over a low divide, across the valley of the South Fork of the Koyukuk, over another low pass, and down Slate Creek to its mouth. The distance by this route is about 175 miles.

During 1910 the Alaska Road Commission commenced the construction of a trail for winter sledding and summer horse packing from Yukon River, which is intended to serve both the Chandalar and the Koyukuk districts. This trail leaves the Yukon at a newly

established settlement named Beaver, situated on the north bank of the river about 100 miles below Fort Yukon. It follows a general northwesterly direction for about 80 miles from Beaver along the rolling ridges that separate the valleys of Orenzik and Hodzana rivers to the divide between them and the Chandalar. Thence it forks into two branches, one to continue northwesterly across the upper part of the West Fork of the Chandalar, across the South Fork to the Koyukuk, and down Slate Creek to Coldfoot; and the other to cross the Chandalar River near Caro and continue northeastward up the Middle Fork of the Chandalar to Grave Creek and up Grave Creek to Little Squaw Creek. During high water small boats can ascend the Chandalar for about 75 miles.

GEOLOGY.

PRINCIPAL FEATURES.

The Koyukuk-Chandalar region is one of diverse geology, and the fragmentary data at hand do not permit a full analysis of all the many problems it presents.

The most widely distributed bedrock of the region is a series of metamorphosed sediments, including some altered igneous rocks, which are here correlated with the Birch Creek schist of the Yukon-Tanana region. These rocks are succeeded to the north, along the central belt of the Endicott Mountains, by a massive semicrystalline limestone, interbedded with some argillites of Paleozoic age, probably Carboniferous. In the western part of the region there is a complex of ancient volcanic rocks, with some cherts and argillites, also believed to be of Paleozoic age (Devonian?), and probably older than the limestone just mentioned.

Mesozoic sediments are represented by a series of limestones, calcareous sandstones, and arkoses with some volcanic rocks, which are regarded as of Cretaceous age. There are also one or two small areas of loosely consolidated conglomerates, sandstones, and shales with lignitic coal beds, which are with reasonable certainty assigned to the early part of the Tertiary period.

The Quaternary is represented by widespread deposits of both fine and coarse glacial outwash, which occurs both as fills in deeply eroded bedrock depressions, the bedrock floors of which are below the present drainage gradients, and as terrace deposits above the present stream levels. The recent stream gravels and silts are largely reconcentrations from the older terrace deposits. Both consist of gravels, sands, and silts. Glacial moraines are also found in the northern half of the region.

The igneous rocks include, besides the volcanic rocks mentioned above, large areas of granitic and dioritic intrusive rocks as well as stocks and dikes of similar composition. The intrusive rocks are locally altered to gneisses. Diabase dikes and sills also occur in some of the formations, notably in association with the ancient volcanic rocks already described. On the lower part of Chandalar River an area of Quaternary or Tertiary volcanic rocks has been noted.

The dominant structural lines trend a little north of east, thus paralleling both the Yukon Valley below the great bend on the south and the main axial line of the Endicott Mountains on the north. The older schists are closely folded, but the Paleozoic limestone series is thrown up into more open folds with many faults. The Mesozoic and Tertiary sedimentary formations are but little disturbed as compared with the older rocks. They are, however, locally folded to some extent and generally more or less tilted and faulted.

GEOLOGIC MAP.

The principal geologic features of the region are graphically summarized on the map (Pl. V, in pocket). In the preparation of this map extensive use has been made of the surveys by Schrader and Mendenhall, whose results have been interpreted by the writer in accordance with his own views of the sequence. As no one geologist has covered the entire field, correlations for purposes of cartography must necessarily be uncertain and the relations of the various formations generalized. It is believed, however, that while this map is far from being accurate it may serve as a useful guide to prospectors by indicating the general distribution of the schists, which are the source of the placer gold, as well as the most important intrusive masses, which are believed to have influenced the gold-bearing mineralization in the schistose bedrock. The mapping of the Mesozoic rocks is also important to the prospector, as these rocks are not likely to be found gold-bearing over belts of any extent. Where they are locally intruded by granite rocks, however, they may contain small bodies of contact-mineralized rock, which yields placer gold, as is the case in the well-known Iditarod district about the head of Flat Creek.

GENERAL SECTION.

The following table shows the geologic column in this region in a generalized manner:

Generalized stratigraphic sequence in the Koyukuk-Chandalar region, Alaska.

Era.	System.	Series.	Lithologic character.
Cenozoic.	Quaternary.	Recent.	Stream gravels, sands, and silts, with muck, peat beds, and "flood-plain" ice, also some glacial deposits within the Endicott Mountains.
		Unconformity.	
		Pleistocene.	Terrace and basin-fill silts, clays, sands, and gravels, with widespread glacial outwash along the southern border of the Endicott Mountains.
	Unconformity.		
	Quaternary or Tertiary.		Effusives, basaltic and andesitic lavas and tuffs.
	Unconformity.		
	Tertiary.		Shales, sandstones, and conglomerates, with some lignitic coal beds.
	Unconformity.		
Mesozoic.	Cretaceous.		Limestones, calcareous sandstones and shales, and arkoses, with some volcanic rocks, and possibly some coal beds.
			Granitic and dioritic intrusive rocks, locally sheared and gneissoid, possibly not all of Mesozoic age.
	Unconformity.		
Paleozoic.	Carboniferous (?).		Massive crystalline and semicrystalline limestones with schistose bands.
	Devonian (?).		Cherts, slates, quartzites, and thin beds of limestone, with basic igneous rocks, tuffs, and alteration phases, some doubtful greenstones and hornstones.
	Unconformity.		
	Pre-Ordovician (?) (Birch Creek schist).		Quartz-mica schists, schistose quartzite, phyllites, slates, amphibolite schist, and highly crystalline limestone. Cut by granitic and dioritic intrusive rocks, mostly of Mesozoic age, but some possibly of Paleozoic age. The gold-bearing formation of the region.

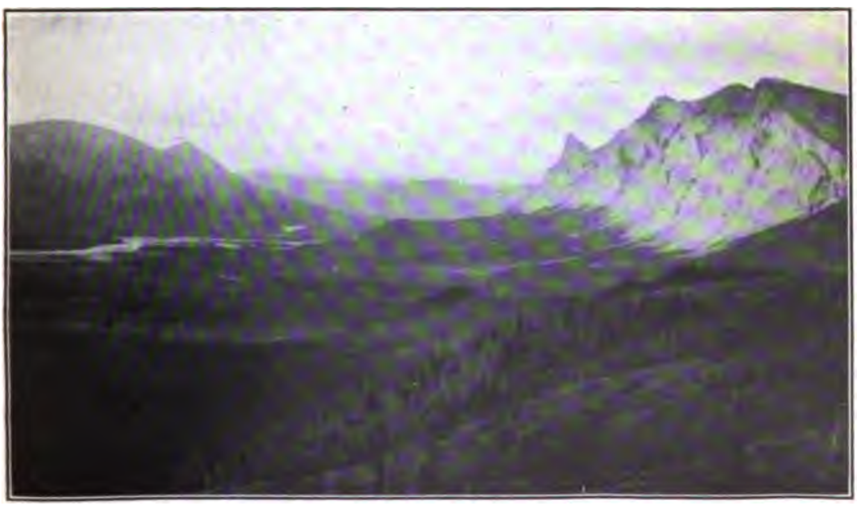
BIRCH CREEK SCHIST (PRE-ORDOVICIAN?).

GENERAL FEATURES.

The Birch Creek schist is in the main composed of highly altered sandstones and shales. Most of the rocks included in this formation have been sufficiently metamorphosed to be in large part recrystallized. The most common rock types are quartzite schists, always containing considerable mica, and finely foliated micaceous and graphitic schists. In the Koyukuk placer district this formation is largely represented by carbonaceous schists, phyllites, and slates. Within the area here mapped as Birch Creek schist there are also some foliated amphibolites or hornblende schists and a few limestones of a highly crystalline and in some places schistose texture. The highly altered igneous rocks of the amphibolite (hornblende) schist

A. LIMESTONE AND SCHIST CONTACT IN ENDICOTT MOUNTAINS.

Looking N. 15° E. from Horace Mountain. Light-colored mountains in background are limestone.



B. LIMESTONE CLIFFS SOUTH OF BETTLES RIVER, A POSSIBLE FAULT SCARP.

type, in part at least, most probably represent metamorphosed basic volcanic rocks that flowed out and became more or less conformably incorporated with the sedimentary rocks comprising the main part of the Birch Creek schist when they were deposited. This inference is drawn from the fact that the igneous schists are in some localities apparently interbedded with the schists of sedimentary origin, and if it is generally correct the relative positions, attitudes, and distribution of some of the amphibolite schists may have more or less stratigraphic significance. On the other hand, in some places these altered basic igneous rocks appear to cut across the sedimentary rocks that contain them, so until the details of their various forms of occurrence are closely studied they will be of little aid in deciphering the history of the schists and can not be separated from them. In addition to these old basic, lavalike rocks the schists also contain, in some areas, large amounts of acidic intrusive rocks of granitic and dioritic kinds, which in some places are closely associated and here and there appear to intergrade in composition. The granitic rocks occur both in large, massive intrusive bodies, locally porphyritic, and in more narrow dikelike forms, which were evidently injected into the country rock, for the most part at a time considerably after the schistose structure of the sedimentary deposits had reached an advanced stage of development.

The schists and the igneous rocks they contain constitute two very widespread belts of bedrock in this region. (See map, Pl. V, in pocket.) One of these belts forms a large part of the Hodzana highland, the irregular area of moderately mountainous relief bounded on the south and east by the Yukon Flats, on the northwest by the Koyukuk Valley, and on the north by a broad depression which separates the highlands from the southern foothills of the Endicott Mountains. (See p. 13.)

The other schist belt makes up the southern ranges and foothills of the Endicott Mountains. The schists are bounded on the northwest by massive crystalline limestones, beneath which they appear to dip, although the contact relations may be those of faulting. (See Pl. VI, *A*.) This schist belt varies in width from 15 to 30 miles, and extends southwestward from the general vicinity of Chandalar Lake across the Middle Fork of the Koyukuk to and beyond John River.

In this region these two belts of schists have been examined only along the routes followed in reconnaissance field work, which necessarily covered but a small portion of the area occupied by a series of rocks of widespread distribution. Consequently the present knowledge of the characters and relations of the Birch Creek schist in this region is too incomplete to permit the separation of the formation

into definite subdivisions. Mendenhall,[1] who examined that part of the Hodzana highland schist belt about the headwaters of Dall and Kanuti rivers, grouped all the schistose sediments and their associated igneous rocks of various type and relations together under the general title "metamorphic complex." He considered this diverse complex to include, in whole or in part, the equivalents of the Birch Creek schist and the Fortymile "series"[2] so widely distributed south of Yukon River; the Kigluaik group, Kuzitrin formation, and Nome group of Seward Peninsula; and the "Rapids" schist and "Lake quartzite schist" of the northern schist belt of the Koyukuk-Chandalar region. This broad classification was suggested because it appears to be the only practical way of grouping together all the older rocks, which present many of the same characteristics and general lithologic features and also show considerable although varying metamorphism, which affects all the rock types however diverse; and because it affords a clear basis for separating them from the younger unaltered, or but little altered, sediments and lavas that occupy the intervening areas.

LITHOLOGY, DISTRIBUTION, AND STRUCTURE.

DALL RIVER AREA.

Mendenhall[3] describes the rocks of the Dall River area as follows:

[*Metamorphic complex*].—The old rocks [of the metamorphic complex] were first encountered along upper Dall River, where the hills in which it heads rise from beneath the silts of the Yukon Basin [Flats]. It is out of these rocks and the granitic intrusives which cut them that the broad ridges and spurs were carved from which the waters of the Dall, Swift [Hodzana], and Kanuti rivers and many Koyukuk tributaries flow. The phase most commonly displayed here is a fine even-grained quartz-biotite schist, with very fine and straight lamination—a true metamorphic rock of uncertain origin. This type makes up the great mass of the schistose rocks of this area. With the intrusives which cut it, it forms the divide between the Yukon and the Koyukuk and the higher parts of the branching spurs where these were examined. * * * Away from the intrusive centers the rock is oftener coarser, less quartzose, and less finely and evenly laminated. Other micas than biotite sometimes appear, and by gradations schists are encountered which are clearly sediments carrying graphite and calcite. Interbedded with schists like these [on both the Dall and the Koyukuk sides of the divide] are three or four bands of gray, often very coarsely crystalline limestone, standing at high angles and striking nearly east and west.

South of the flats at the head of the Kanuti River a series of dark fine-grained slates and dark quartzites form the lower slopes of the wall of the valley.

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[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, pp. 31–37.

[2] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 140.

[3] Mendenhall, W. C., op. cit., pp. 32–33.

Intrusives.—The schists [of the Hodzana highland] are extensively cut by uniform bodies of granite porphyry, which in some parts of the region occupy greater areas than the rocks into which they have been forced. These masses are particularly abundant north of the upper course of the Kanuti River [on the divide between it and the southern branch of Fish Creek] and among the hills northwest of the eastern branch of the Dall. * * *

On the [west side of the main] Dall River [a few miles above the point where it leaves its valley to enter the Yukon Flats] granites which are not porphyritic and not schistose, though deeply weathered, outcrop along the stream section [and extend southwestward, forming the foothills that bound the northwestern part of the Yukon Flats. These are intruded into the schists. About 15 miles west of the mouth of Dall River a massive body of porphyritic granite forms a rounded mountain about 3,000 feet high]. On the hill slopes to the north [of Dall River] occasional narrow and compact acid dikes are exhibited. These are regarded as offshoots from the main intrusive mass.

In addition to these unaltered intrusives, gneissoid porphyritic rocks of granitic and dioritic composition occur in the schists. Sometimes the crushing has gone so far as to suggest that some of the biotite schists may themselves be derived from igneous rocks of like character, but as no instance was observed in which the distinction could not be clearly made, this suggestion remains unproved. It is true, however, that the intrusion began before the metamorphic action had ceased, so that the earlier intrusives were greatly affected by it.

The geologic time at which the granitic intrusive activity was at its maximum development is not determinable from any stratigraphic evidence in the area under consideration, but its general development in other parts of Alaska, especially throughout the widespread areas occupied by the Birch Creek schist, indicates it to be a characteristic event of much geologic importance, both historically and economically, for in many places the bedrock mineralization that has been stimulated by these intrusions seems to have produced the gold-bearing zones from which the placer gold has been derived. In certain areas of minor extent the Birch Creek schist is unconformably overlain by sediments of Cretaceous age, both the younger sedimentary rocks and the old schists being cut by the same granitic intrusive rocks which occur so commonly in some portions of the schists. From this evidence it is provisionally inferred that most of the granitic rocks were intruded during later Cretaceous time. Although at some localities the Cretaceous sediments are somewhat generally altered over considerable areas, at others they have been affected only slightly by contact metamorphism. This might be interpreted as evidence that the more active metamorphic influences culminated at about the close of the period of granitic intrusive activity.

The schists that extend northward from Fish Creek to the southern branches of Jim River appear to be quite free from intrusive rocks, but the northern front of the Hodzana highland, from the headwaters of Jim River eastward along the south side of the Chandalar Valley to a point opposite the mouth of the East Fork of the Chandalar,

is made up largely of a belt of intrusive granitic rocks. The west end of this belt of rocks is composed mostly of porphyritic granites. Toward its east end, along the south side of the Chandalar, it is in large part a gneissoid granite which is considerably crushed and sheared and shows the effects of dynamic action, being in some places so highly sheared and altered as to partake of the nature of a granitic mica schist. In some zones the rock is so folded, jointed, and cleaved that it can not be distinguished ordinarily from a true biotite schist. These older phases are intruded by an apparently younger and fresher-looking granitoid rock, which is medium grained and more or less porphyritic. On fresh surfaces this rock has the appearance of a typical gray granite; in composition it is found to be a granodiorite. It occurs as dikes in the gneissoid rocks, which are also cut by narrow acidic aplite dikes of a light-gray color composed of fine and even grained quartz and feldspar, with a very small amount of green, apparently chloritic mica.

Along the south side of Chandalar River the granitic rocks have a known extent of 25 miles. From the reports of prospectors they are judged to continue westward to the area known to occur on upper Jim River and southward for some distance as the most common rock of the broad, even ridges and higher mountain areas in the northern part of the Hodzana highland.

The dominant bedrock structural features throughout the Hodzana highland trend generally in directions from east-west to northeast-southwest, and the longer dimensions of the intrusive masses and dikes usually follow the trends of the schists that contain them.

KOYUKUK-CHANDALAR AREA.

GENERAL FEATURES.

The Birch Creek schist as developed in the northern Koyukuk-Chandalar belt was provisionally divided into three formations by Schrader, who separated the schists on the basis of lithologic and structural differences, which, though evident enough at particular localities, have not yet been studied with sufficient detail to make it possible to distinguish and separate their varying phases with facility throughout the region. It will be impracticable to apply these probable divisions of the metamorphosed sediments with any degree of exactness until their areal development and distribution have been carefully traced and plotted upon a map of sufficient detail to show their complicated structural and lithologic interrelations. The three divisions of schistose rocks recognized by Schrader[1] were named—in ascending order from those which he at that time thought the oldest—

[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 472–475.

the Rapids schist, the Amphibolite schist, and the Lake quartzite schist. Schrader considered that only the youngest of these three divisions, the "Lake quartzite schist," might probably be correlated with the Birch Creek chist, as originally defined by Spurr[1] in the Fortymile and Birch Creek placer districts, south of Yukon River, where this name was applied to a group of rocks "consisting mostly of quartzite schists, grading into finer-grained, often graphitic schists." Schrader also recognized, however, the possibility that the "Rapids" schist is merely a lithologic phase of the lower part of the "Lake quartzite schist"—in other words, that these two divisions should be more properly considered as comprising one unit, for he says, "It [the "Rapids" schist] seems to underlie the Lake quartzite schist, but may prove to be a lower member of this series, so altered by metamorphism as to bear little resemblance to the general [and more widespread] type [of the "Lake quartzite schist"]." For the present, at least, the writer is inclined to consider the schists of sedimentary origin as a unit rather than attempt to separate them. In this connection it may also be well to suggest the possibility that the amphibolite schist is in reality younger than the "Lake quartzite schist," on the ground that it may represent a highly metamorphosed phase of diabasic or dioritic effusive or intrusive rocks which were either poured out upon the sedimentary beds of the "Lake quartzite schist" before they were altered into their present highly schistose condition or intruded into them before or early enough during the period of their metamorphism to have suffered the same changes in greater or lesser degree, at least in some areas. In the present report it is deemed most satisfactory to consider Schrader's three groups of schists to be merely members of the Birch Creek schist as this formation is now defined. The principal parts of Schrader's descriptions as qualified above are given below, with only such modifications of arrangement and slight omissions as are necessary to fit them to this necessarily generalized interpretation.

"RAPIDS" SCHIST.

This term refers to a narrow belt of highly metamorphosed or altered mica schist traversed by the Chandalar River in the region of the rapids [about 8 miles below Chandalar Lake], where the schist forms a low anticline, with much quartz, in the bight of the fold. Here the rock embracing the rapids extends for several miles downstream [to Horse Creek]. This rock in geological horizon is supposed to [be the oldest]. It seems to underlie the Lake quartzite schist, but may prove to be a lower member of this series, so altered by metamorphism as to bear little resemblance to the general type. In the region of the rapids, and to some extent below, the rock is a biotite schist, closely appressed or crowded into numerous short folds, and contains much quartz, some garnet, and other metamorphic minerals.

[1] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 141.

The trend is east and west. At a short distance below the rapids the dip is southward, while above the rapids it soon becomes northerly. [This formation was noted along the river and extends southwestward across the valley of Horse Creek.] From its mineralized character it would ordinarily be regarded as one of the most auspicious to be examined for mineral resources. [Prospects of placer gold are reported to occur in the gravels of Horse Creek.]

On the Middle Fork of the Koyukuk, at the mouth of Bettles River, occurs a small area of what appears to be much the same rock. [It seems to dip beneath the heavy-bedded limestones that make up the mountains to the northwest, but the stratigraphic relationships in this vicinity are complicated by faulting.]

AMPHIBOLITE [HORNBLENDE] SCHIST.

[This rock] is a fine-grained fissile or fibrous schist of apple-green color. [Some of it is so siliceous as to] partake largely of the nature of a micaceous quartz schist. The quartz, however, is [generally] disposed in small bands and veinlets, all of which have suffered flexing and folding, the small folds often occurring in the most recumbent manner. The presence of sulphides and occasionally carbonates denotes mineralization. Assays of the contained quartz show it to carry both silver and gold [specimens obtained near the base of Green Mountain, on Chandalar River, yielding about 0.42 ounce of gold and 0.14 ounce of silver to the ton of quartz, or a money value of about $8.50 a ton of picked specimen quartz].

Judging from the apparent position of this rock in the geologic horizon it ranks among the older rocks of the region. It is apparently younger than the Rapids schist, and it seems to occupy a lower horizon than the Lake quartzite schist, which may provisionally be referred to the Birch Creek series. * * * It occurs on Chandalar River, about 3 miles above Bend Mountain. Here it is not, as usual, restricted to the floor of the valley, but seems to be the conspicuous rock in a mountain of moderate size known by the prospectors as Green Mountain. Along with gray mica schist and limestone, it forms the mountainous slope fronting the valley to the north. Back of this front it seems to have a somewhat wider extent to the northward. At the base of Green Mountain, near the edges of the valley, the schistosity trends northeast and southwest, with dip gently northwestward. * * *

In the floor of the [Chandalar] valley a few miles below Portage Creek the schist forms a low bench of some prominence, whose surface is about 25 feet above the present level of the river. It was next met with on Robert Creek, at about the same elevation as on Chandalar River, to the northeast of Horace Mountain, where it exclusively forms the low bluffs and benching along the northeast side of the creek. It occurs also in Robert Creek canyon. On Dietrich River, at about 5 miles below Fault Mountain, on the north edge of the valley, it again forms a low bench rising to about 20 feet above the river. The trend of the schistosity here is northeast and southwest, with a dip of about 35° southeastward. Here the rock also has a pitch or plunge structure, with a dip of about 20° southeastward. A couple of exposures of limited extent were also met with at the base of the mountains along the Middle Fork of the Koyukuk River, between Bettles River and Slate Creek. Here gray micaceous quartzite schist, probably referable to the Birch Creek formation, seems to rest upon it.

"LAKE QUARTZITE SCHIST."

[This formation] so far as observed is principally a micaceous quartzite schist, though in some localities the mica becomes the dominant essential

mineral. The quartz grains are usually rolled and rounded, denoting a sedimentary origin. Besides biotite, which is usually greenish, some muscovite and chlorite also occur. Magnetite as an accessory is often present in considerable amount. Garnet has been sparingly noted. In some instances the minerals are considerably crushed and the foils of biotite mica bent and flexed about the quartz. In other cases there is present considerable graphitic material, giving to the rock occasionally the aspect of a graphitic schist. The rock carries some quartz veins of moderate size, trending usually parallel with the schistosity, while some deviate or run nearly at right angles to it. A few exhibit mineralization, though this is not pronounced.

This rock is here called the Lake quartzite schist because of its great prominence at Chandalar Lake. In the bend of the lake [on its west side] it forms a steep-faced cliff, rising nearly 2,000 feet above the lake, offering a fine exposure of structure and jointing. It seems probable that with future examination this rock may be correlated with the Birch Creek schists [south of Yukon River].

Geologically this rock overlies the Rapids schist, and it apparently underlies the limestone series on the northwest. In distribution it seems to extend from near the West Fork of Chandalar River [Crooked Creek] northward to beyond the lake, and from east of Chandalar River westward to the Middle Fork of the Koyukuk. It is apparently one of the chief rocks constituting the rugged mountainous mass [between these rivers, some of the peaks of which rise] to a height of nearly 6,000 feet.

From near the West Fork of Chandalar River to near the rapids the dip is southerly, but above the rapids, near the head of the lake, it becomes gently northwestward, the divergent dips apparently denoting the two sides of an anticline, the rock being thus more or less conformable with the Rapids schists. [The strong probability that the "Rapids" schist is merely a lower member of the widespread schist group of this area has already been stated.]

Concerning the more widespread areal distribution of the Birch Creek schist in the Chandalar region, it may be said that the formation is known to extend northeastward at least as far as the Lake Creek and Grave Creek valleys, and that prospectors report its occurrence farther east on the headwaters of the Middle Fork of the Chandalar.

INTRUSIVES.

In the Koyukuk-Chandalar belt of Birch Creek schist granitic intrusive rocks do not appear to be as extensive or as widely distributed as they are in the Hodzana highland belt. The only considerable area of them now known appears to form a prominent part of the high rugged range which extends northeastward from the head of Baby Creek to the elbow of Chandalar River at Bend Mountain, about 15 miles above Chandalar Lake. On the northeast the granitic rocks appear to cross Chandalar River and extend into the Bend Mountain area. Their extent southwestward from Baby Creek is not known, but the high, rugged topographic forms that seem to be characteristic of their massive occurrence appear to diminish in this direction. West of these mountains, however, granitic rocks appear to extend

across the valley of Robert Creek to Horace Mountain, opposite the mouth of Sheep Creek. Northeast of Horace Mountain the intrusive rock extends in the direction of Geroe Creek and Bend Mountain. Southwest of Horace Mountain, for a distance of 10 miles, nearly to Limestone Creek, the same rock seems to form a somewhat prominent line of rugged peaks rising to heights of nearly 6,000 feet along the northwest side of Bettles River.

The rock of the Baby Creek area has received only a cursory examination, but seems to be a granodiorite, being composed of feldspar, with some quartz, hornblende, and green mica. It is a light-colored rock with greenish tinge and medium grain. Locally it has been considerably sheared and altered to schist, but a large part of it seems to be in a comparatively unaltered condition. It is probably the bedrock source of the fresh granitic bowlders that occur in considerable quantities throughout the unconsolidated filling of the Chandalar Valley below Bend Mountain. In fact, the present channel of Chandalar River from the rapids below the lake to the mouth of the Middle Fork is clogged with bowlders of this kind of rock, which, owing to the considerable grade of the valley throughout this section, are so disposed as to form an almost continuous succession of swift riffles.

At a point about 3 miles south of the head of Chandalar Lake the schists are cut by a greenish dioritic dike several hundred feet in thickness, which has a northeast-southwest trend. East of Chandalar Lake the mountain mass on which Big, Tobin, Bowlder, Big Squaw, and Little Squaw creeks have their sources contains a considerable amount of dioritic intrusive rock with which the gold-bearing quartz veins of this locality appear to be associated. (See p. 111.)

The intrusive rock of Horace Mountain is also of a dioritic nature. The upper thousand feet or more of this mountain is apparently a large dike intruded into the schists of this region. The intrusive character is inferred from the completely altered condition of the country rock along the zone of contact, which in some places is 100 yards or more in width. The trend of this intrusive rock is northeast and southwest. In texture it varies from a medium-grained, somewhat gneissoid rock to a schist, and in its various stages it seems to show passage by dynamic action from a greenish-gray speckled augite diorite to an amphibolite schist. The southeastern slope of the mountain is traversed by a more or less mineralized belt a quarter of a mile wide. Here the rock seems to consist principally of quartz, which is greatly crushed, sheared, and folded and is stained a bright red. The staining material has not been examined closely, but is probably hematite.

Intrusive rocks are much less prominent to the west, in the Koyukuk area of the schist, than in the Chandalar district. With

the exception of a dioritic dike on Gold Creek, another that crosses Myrtle and Slate creeks, and the rocks reported to occur in the mountains between the sources of Emma and Wiseman creeks and possibly west of Nolan Creek, a northern tributary to Wiseman Creek, no igneous rocks, either intrusive or effusive, have been noted in this area.

The Gold Creek dike is situated about 3 miles above the mouth of that stream, where it forms a small canyon several hundred yards long. It strikes northeast and southwest and stands about vertical. Its outcrop is noticeable up the north slope of the valley to its crest, but beyond this point its extent has not been traced. To the southwest from the point where it crosses Gold Creek it has been observed for only a few hundred yards, being covered beyond by talus and vegetation.

The intrusive rock reported to occur in the mountains on which Emma and Wiseman creeks have their sources was not observed in place by the writer, but the numerous large dioritic bowlders in the gravel deposits of the Emma Creek valley, which, according to the statements of prospectors, are derived from intrusive bodies in the mountains about the head of the creek, indicate that considerable masses of this rock occur there. Some bowlders of this same kind of intrusive rock occur in the gravels of the Wiseman Creek valley, and may be derived from the same mountains or from the ridges west of Nolan Creek, a north-side tributary of Wiseman Creek.

The intrusive rocks on Gold and Emma creeks lie in a broad way along the general strike of the schistose country rocks that contain them, and are in trend with the belt of intrusive rocks which extends along the northwest slope of the Bettles River valley from Horace Mountain to a point near the mouth of Limestone Creek. There is, however, no evidence at hand to show that these rocks are in direct relation with each other, but it may be that they were intruded at the same time under similar conditions.

A dike similar to those on Gold Creek and Chandalar Lake occurs on Myrtle and Slate Creeks, in the Koyukuk district. It crosses Myrtle Creek about 1½ miles above its mouth and extends southwestward across Slate Creek about 2 miles below the mouth of Myrtle Creek. It also extends northeastward into the mountains that form the southeast side of the Myrtle Creek valley, where it has the same general strike (northeast-southwest) and dip (35°–55° SE.) as the schists which contain it. The northeastern extension of these mountains may also contain more or less of this intrusive rock, for the valley of Boulder Creek, about 8 miles east of Myrtle Creek, has a considerable quantity of bowlders and cobbles of this kind of rock in its stream gravels.

JOHN RIVER AREA.

On John River, about 50 miles west of the Middle Fork of the Koyukuk, Schrader[1] observed a highly schistose group of rocks which he described under the name Totsen series, but which are here classed with this belt of Birch Creek schist. Schrader's description is in part as follows:

TOTSEN SERIES (SILURIAN).

Character and occurrence.—This series of rocks occupies a belt about 12 miles wide on John River. It lies south of the Skajit formation [which consists of heavy-bedded crystalline limestone and mica schist resembling and probably corresponding to the more schistose phase of the Bettles "series" that occupies the northern part of the Koyukuk-Chandalar region. On the south it is unconformably overlain by the Bergman "series," consisting of unaltered sediments of Cretaceous age. The rocks of the Totsen "series"], are mainly mica schists and quartz-mica schists, in both of which the essential minerals are biotite and quartz. There is also some much-altered greenstone or amphibole schist. Locally the mica schist becomes graphitic, graphite bodies one-eighth inch in diameter being noted, and in some cases the rock carries much secondary quartz, both in small veins and in lenticular bodies. Some iron pyrite is also present, which on oxidation gives a reddish-brown color to the rock. The quartz veins tend to follow the schistosity and are often locally contorted and twisted. Some carry irregular veinlets or stringers of epidote.

The series is believed to be essentially of sedimentary origin, but the sedimentation seems to have been accompanied by basaltic flows, which were later sheared with the sedimentary beds, giving rise to amphibolite schist, of which the most prominent strip, having an apparent width of several miles, occurs near the southern part of the belt occupied by the series [as exposed along John River]. Here the [amphibolite] rock, judging from the bent and crushed remnants of feldspar and augite shown under the microscope, is plainly of igneous origin. Though on account of faulting and folding there is doubtless some duplication of the rocks of the Totsen series [as it occurs along John River], its total thickness, judging from the prevailing dip and distance across the strike, is 6,000 and 7,000 feet.

Structure.—The Totsen series, like the older rocks composing the range, trends approximately east and west, and though the series as a whole has been intensely folded, the dip in general is monoclinal, being, so far as observed, southward, at angles of 60° to 80°. [It must be borne in mind, however, that such a monoclinal attitude may be that of overturned folds whose tops have been truncated.] In the northern part of the belt John River valley, for a distance of several miles, seems to follow a north-south syncline in the series. The series is traversed by the major northeast jointing of the range and by a secondary structure at nearly right angles to the major jointing. Cleavage was noted at a few localities, but apparently much of this has been obliterated by disturbance.

Age and correlation.—The Totsen "series," so far as observed, "consists essentially of rocks that seem undoubtedly to belong to the class of older crystalline schists" which are so widely distributed

[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 58–60.

throughout the interior of Alaska. As far as now known it can not be correlated with any of the formations that make up the major part of the Endicott Mountains to the north, for all of these are apparently younger.

According to Schrader, "the Totsen series can be correlated in a tentative way, on lithologic grounds, with the Lake quartz schist of Chandalar River." As made up in the section exposed along John River these rocks appear to be more micaceous and to contain much less quartz and more greenstone schist than the thick members of sedimentary origin that occur in the Koyukuk and Chandalar districts. Nevertheless, at some localities on John River the Totsen very much resembles the more altered phases of the schists east of the Koyukuk, in the Slate-Myrtle Creek placer diggings, which in turn have been correlated with the "Lake quartzite schist" of Chandalar River.

SUMMARY.

CORRELATION.

The country rock of the Hodzana highland and the Koyukuk and Chandalar gold districts is largely made up of different kinds of highly altered sedimentary rocks, which are similar to and apparently in large measure the same as the old formations that are known to form the bedrock over extensive areas throughout the interior of Alaska, both north and south of the Yukon and westward into the Kobuk Valley and Seward Peninsula. These old schistose rocks may be differentiated into several indefinite groups, but in general it is most satisfactory for the present to assemble them together, for they show many similar characteristics and intimate interrelations, especially in regard to their widespread regional metamorphism and the economically important fact that the mineralization developed within them during their transformation was accompanied by the segregation of gold-bearing minerals in some of their members, from which free gold has been derived and concentrated into placers.

In the region under consideration these rocks make up a diverse complex of more or less schistose sediments, in some places associated with igneous rocks of various types and relations. Many different phases of the schists have been recognized, but because of the variations in the rocks from place to place enough evidence to warrant their definite subdivision, correlation, and classification has not yet been gathered, particularly in the region north of the Yukon. South of the Yukon, between that river and the Tanana, the general sequence of the rocks, beginning with the oldest, appears to be quartzite schists, carbonaceous and graphitic schists, quartz-mica schists, garnetiferous schists, crystalline limestones, and altered igneous rocks largely intruded into the sediments. These rocks are called the Birch

Creek schist and are considered to be of early Paleozoic age, probablv pre-Ordovician. North of the Yukon rocks that are considered to belong to the Birch Creek schist occupy two wide belts which have been described on pages 34-45. The rocks of the Hodzana highland belt appear to be similar in every particular to those of the Yukon-Tanana region and contain a considerable amount of igneous intrusive rocks, mostly granite porphyries, both unaltered and metamorphosed. This belt of Birch Creek schist appears to extend more or less continuously southwestward along the divide between Kanuti and Yukon rivers and probably connects with the Birch Creek schist that occurs in the Gold Hill district, on the north bank of the Yukon about 25 miles below the mouth of Tanana River.

The northern or Koyukuk-Chandalar belt of Birch Creek schist is 10 to 30 miles wide, extending from the Chandalar Lake region across the Koyukuk Valley between Slate and Gold creeks and southwestward across the lower John River valley. Its distribution east of the Chandalar Lake region is not known, but to the west and southwest it extends to the Kobuk Valley and Seward Peninsula, where part of it forms the gold-bearing bedrock of the Nome, Candle, and other districts. On Slate Creek and generally throughout the Koyukuk placer district a phase of the Birch Creek schist consisting of carbonaceous schist, phyllite, and slate is common. To the northeast, in the vicinity of Chandalar Lake and southward along Chandalar River to Horse Creek, these rocks are more quartzitic and micaceous but also contain graphitic phases. To the southwest the lower part of the John River valley is crossed by a belt of schistose rocks, largely of sedimentary origin, which are locally graphitic and contain much secondary quartz, like the Carbonaceous schists of the Slate Creek valley. In the Koyukuk area the Birch Creek schist does not appear to contain the large amounts of igneous intrusive rocks that are characteristic of the area between the Tanana and the Yukon and of the Hodzana highland.

STRUCTURE.

The broad general trends of the dominant structural features of the Birch Creek schist throughout both the Hodzana highland and Koyukuk-Chandalar belts vary from east-west to northeast-southwest. The dips of the bedding planes are for the most part at steep angles to the north or south, being in many exposures nearly vertical, but some dips are as low as 35°. For some of the broad sections that show generally consistant dips in opposite directions from or toward assumed axes of folding, which have not been definitely located or traced, tentative interpretations of anticlinal or synclinal structure have been suggested. What appear to be sections of considerable stratigraphic thickness across some areas where the strike

and dip are uniform give the impression that a monoclinal structure prevails. Such attitudes of the schists, however, may prove, when opportunity offers for examining them closely, to be largely accounted for by profound overturned folds whose tops have been truncated by erosion, and the faulting, some of which may be of the overthrust type, may also be a factor that enters into the present structural attitudes of the schists to an extent that can not be defined without detailed study.

As a rule the longer dimensions of the intrusive rock bodies follow more or less closely the general structural trends of the schists that contain them, whether they occur as large masses, some of which are several miles wide and 5 to 15 miles or more long, or as much narrower dike-like bodies. Many of these intrusive rocks, both the massive and the dike-like forms, show strongly developed shear and joint fracturing, and in some places they have suffered metamorphic alteration to the extent of assuming gneissoid structure, especially along the margins of the larger granitic masses. Locally considerable bodies of the granitic rocks are gneissoid throughout.

MINERALIZATION.

In general the transformations that have taken place in the mineral constitution of the Birch Creek schist are of the kind that have affected, over widespread areas in greater or lesser degree, all the members comprising the formation. The present condition of the rocks is the result of what is called regional metamorphism, in distinction to the similar mineral alteration termed contact metamorphism, which is not only of much less areal extent but is confined to narrow zones along the immediate contacts of intrusive rocks with country rocks.

Although the Birch Creek schist is made up of rocks that resulted primarily from regional metamorphism, it has also been affected secondarily by a minor amount of contact metamorphism. The contact-metamorphic effects are most evident in connection with granitic intrusives, which evidently entered the country rocks after they had become transformed partly, if not wholly, to a schistose condition. In fact, the occurrence of contact-metamorphic alteration about the borders of these intrusive rocks constitutes the principal evidence as to the relative time when the granitic rocks were intruded and when the mineralization they stimulated took place. But even this evidence is far from conclusive, for at many localities the problem of determining when the intrusion and its accompanying contact mineralization occurred is complicated by the fact that some of the granitic rocks also have suffered metamorphism since they were intruded, as is shown by their gneissoid or schistose structure. These diverse conditions throughout the two schist belts under consideration make it im-

possible to state whether the intrusion of all the granitic rocks and the resulting contact mineralization took place at the same time and the rocks were subsequently affected by further metamorphism that was more intense in some localities or rocks than in others, or whether the granitic rocks were intruded at different times throughout the long period of general regional metamorphism and for this reason show different degrees of alteration. This question apparently has an intimate relation with the origin of at least some of the gold, for in some places the gold-bearing mineralization seems to be directly connected with the effects of igneous contact alteration. At other localities, however, such a relation, if it originally existed, has been so obliterated by further metamorphism as not to be evident.

One of the most common and easily observed changes that occurs in the metamorphism of rocks, whether of the widespread regional or more localized contact character, is the rearrangement and redistribution in various forms of the silica or quartz contained in the original rocks before they became altered and in such intrusive rocks as may become associated with them before, during, or after their transformation. Not only may the quartz be changed from its original condition and form by recrystallization in place or nearly in place in the parent rock matrix, but large amounts of it may become dissolved in circulating waters which may contain also mixtures of other minerals in solution. These mineralized solutions may migrate through the country rocks, perhaps for considerable distances, and be redeposited elsewhere in various forms as secondary quartz, the term secondary being used in the sense that the quartz has changed from its primary condition with reference to its original position or mode of occurrence in the rocks of which it is a constituent.

Secondary quartz is the most common and widespread gangue or cementing material found in rocks that have been disrupted and otherwise deformed by geologic forces. The manner and form of the changes and migrations the quartz undergoes in being deposited secondarily depend on the chemical nature and physical condition of the rocks through which and into which it circulates in liquid form. The quantity of quartz thus deposited is far greater than that of any other mineral. Generalized estimates indicate that under favorable conditions probably 90 per cent or more of all the openings, both large and small, produced in rocks by metamorphic deformation—such as faults, fissures, joints, bedding partings, and the minute spaces between laminæ, grains, and the smallest particles that compose the rocks, whether they are the result of fracture, flexure, flowage, or simply the natural porosity of some beds—become infiltrated or filled by a cement of quartz. Generally the quartz assumes the forms of the spaces it occupies. These vary according to the kinds and conditions of the rocks. The coarser-grained, more rigid rocks

usually have larger, more regularly disposed, and continuous clean-cut openings or fractures, along which veins of considerable size are deposited. The finer-grained, less rigid rocks present spaces of irregular size and shape which may have a disordered arrangement, suggesting that they have been kneaded. In these the secondary quartz usually tends to follow the schistosity of the country rocks as small contorted and twisted veins and lenticular bodies, some of which may be of considerable size, with knotty bunches and smaller crosscutting veins and leaflets disseminated between them, which for the most part are irregularly disposed and somewhat disconnected. Where a series of schists is made up of alternating harder and softer members, like the Birch Creek schist, the rocks are usually fractured in the former and flexured in the latter, and as a consequence the secondary quartz generally shows the differences in manner of deposition noted above. A great variety of both these modes of deposition of secondary quartz, with all possible intergradations from one to the other, is characteristic of the Birch Creek schist as it occurs in the Hodzana highland area and in the Koyukuk and Chandalar districts.

Where dissolved metallic minerals become mixed with solutions of quartz they generally solidify in more or less close association with the quartz, where it is redeposited under favorable conditions. Gold, both in its native state and in association or combination with metallic minerals, such as the sulphides of iron, silver, arsenic, and lead, occurs in many places with secondary quartz thus redeposited from solutions. The quartz either wholly or partly fills the spaces in the rocks, and if metalliferous compounds are present they are generally deposited also, either intermingled with the quartz or closely associated with it.

In the Chandalar district, where gold-bearing quartz deposits of importance are known to occur within a small area at the source of Big Creek, it seems to be evident that the gold is connected with veins of quartz in zones of contact alteration surrounding or connecting bodies of dioritic intrusive rocks. In the Koyukuk district the close genetic relationship of the gold to contact mineralization is not so apparent, but some intrusive dioritic rocks are known to occur there (see pp. 42–43), and more detailed examination may show that the bedrock source of the gold is closely connected with zones of contact alteration.

PALEOZOIC ROCKS.

SUBDIVISIONS.

There are two groups of rocks in this region which, though with little doubt of Paleozoic age, can not now be assigned definitely to any period in that era. Even the relative age of one compared with the

other can not be stated with any satisfaction. They are quite different lithologically and are not known to occur in contact with each other in the region under consideration. One of these groups is made up largely of massive crystalline limestones. The possibility of its being either upper Silurian or lower Carboniferous has been suggested, but at present the lower Carboniferous age of these limestones seems to have more evidence in favor of it. The other group, which may be of Devonian age, comprises a series of cherts and slates with some dark fine-textured quartzites and a few thin beds of limestone, together with compact greenstones, fine-grained pyroclastic rocks, basalts, and intrusive diorites.

DEVONIAN (?) ROCKS.

CHARACTER AND DISTRIBUTION.

Mendenhall[1] has described a complex of volcanic rocks, which occurs in the southwestern part of this region, under the name Kanuti series. This complex is made up of greenstones, pyroclastic rocks, basalts, a large amount of intrusive diorites, and some hornstones or dense flinty shales, the whole series being intruded by granites.

Rocks of a somewhat similar character occur on Yukon River at the southern boundary of the region under discussion. These rocks, which have been studied by Prindle,[2] are made up of greenstones of various types, chiefly volcanic, together with slates, cherts, and limestones. Some volcanic rocks, cherts, and slates seen by the writer on the South Fork of the Koyukuk and between the South Fork and Slate Creek are provisionally correlated with this group, as are also somewhat similar rocks along the west side of Chandalar River between its West Fork and Crooked Creek, named by Schrader[3] the West Fork series. This series consists of fine-grained quartzite, dark flint, calcareous black shale, and impure limestone, intruded by dioritic and greenish diabasic dikes that follow the structure of the country rock, which trends from northeast to southwest. It forms the bedrock of the broad area between West Fork and Crooked Creek and the rolling divide about their sources 12 to 15 miles west of the Chandalar. This belt, which is about 15 miles wide, corresponds with the broad depression that lies between the Hodzana highland on the south and the southern flanks of the Endicott Mountains on the north and extends westward from the lower Chandalar Valley to that of the Middle Fork of the Koyukuk.

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[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, pp. 37–38.

[2] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908, pp. 18–22.

[3] Schrader, F. C., Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 475–476.

Schrader considered that these rocks extended westward and southwestward to the Middle Fork of the Koyukuk in the low mountains 5 to 10 miles south of Slate Creek and on the South Fork of the Koyukuk in the vicinity of Jim River, where they have been observed by the writer. He also suggested their probable eastward extension to the East Fork of the Chandalar and possibly to Porcupine River, where a series of shales, limestones, and diabase occurs in the lower part of the Upper Ramparts.

The facts at hand do not warrant any definite statement in regard to the structure of these rocks, except that they are considerably deformed and much fractured. Some quartz veins occur in the fracture spaces, and they may be locally mineralized, but so far as known they have yielded no deposits of value.

AGE AND CORRELATION.

There is no direct evidence regarding the age of this assemblage of rocks. They are apparently in unconformable relations with the Birch Creek schist. Schrader found a few fossils referable to the Devonian in gravels and cobbles along Chandalar River and the South Fork of the Koyukuk, which on the basis of their lithologic similarity to beds in his West Fork series he considered to be derived from that source. Mendenhall correlated his Kanuti series with Spurr's Rampart series and provisionally assigned them to the middle of the Paleozoic. A few fragmentary fossils from rocks of this general group on the middle Yukon in the area here under discussion belong at the same general horizon. On the upper Yukon between Eagle and the Yukon Flats volcanic greenstones, some of which are interbedded with and all of which are more or less closely associated with shales and limestones, are in close stratigraphic relation with Middle Devonian limestones. There is a similar association of Middle Devonian limestones with greenstone volcanic rocks and shales on Porcupine River in the lower part of its Upper Ramparts. Altogether the assemblage of rocks with these general characters and interrelations appears to have a widespread development throughout the central Yukon Valley, and wherever paleontologic evidence has been found it points toward the Devonian age of the rocks.

CARBONIFEROUS (?) ROCKS.

LITHOLOGY, STRUCTURE, AND DISTRIBUTION.

The northwestern part of the area under consideration is almost wholly occupied by a series of massive semicrystalline and crystalline limestones interbedded with some mica schists. The limestone is much jointed and in many places very schistose. Many of the fractures have been filled with calcite and some of them with quartz, and

a few of these were observed which contain pyrite, chalcopyrite, or galena. In general, however, the rocks do not seem to be mineralized. Their usual color is light gray or dingy marble-white, but they include also darker members, and here and there extensive exposures stained iron-red and brown are conspicuous.

As a whole they seem to be thrown up into a number of folds whose axes run about east and west. Schrader found evidence of strong fault displacements in the limestone, which seems to account for some of the peculiarities of distribution of these rocks in the northern part of the field and for their generally rugged forms and the steep scarps which form very conspicuous topographic features in many places. (See Pl. VI, *B*, p. 34.) Considerable faulting has occurred along their southern border, where they are in contact with the Koyukuk-Chandalar belt of Birch Creek schist, which passes beneath the limestones. The limestones may be overthrust upon the schist.

So far as known these limestones make up practically all the central ranges of the Endicott Mountain belt. Within the area covered by the map (Pl. V, in pocket) their somewhat irregular southern boundary is seen to extend from the upper Chandalar, whose valley they cross about 35 miles above Chandalar Lake, southwestward along the northwest slopes of the valleys of Robert Creek and Bettles River to Dietrich River. Here there is a conspicuous isolated outlying mass between the lower 5 miles of Bettles River on the east and the upper 5 miles of the Middle Fork of the Koyukuk on the west. (See Pl. VI, *B*, p. 34.) The boundary of the main body of limestone extends northward from lower Bettles River along the east slopes of the valley of Dietrich River for about 20 miles and then crosses to the west side of the valley. (See Pl. VI, *A*, p. 34.) Thence the limestones extend southwestward for about 80 miles in a belt of irregular outline to John River, which they cross about 40 miles from its confluence with the Middle Fork of the Koyukuk.

AGE AND CORRELATION.

Schrader[1] first described these limestones and associated schists under the name Bettles series, but did not assign them to any definite place in the stratigraphic column. Later he described, under the name Skajit formation,[2] a belt of limestones about 20 miles wide on John River, which because of their resemblance to the schistose, crystalline, and micaceous phase of the Bettles "series" are provisionally correlated with that series. Some poorly preserved fossils collected

[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 475.

[2] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 56–58.

from the Skajit formation in place include the remains of a brachiopod, which indicates an age not older than upper Silurian and not younger than lower Carboniferous.

These limestones are certainly younger than the Birch Creek schist and presumably are the equivalent of at least one or possibly more of the Paleozoic limestones of the Yukon Valley. Of these there are four—the Ordovician, Silurian, Devonian, and Carboniferous. East of the Koyukuk-Chandalar region, along Porcupine River, all four of these geologic systems are represented, the stratigraphic position of the limestones having been well established by the fossils they contain. Across the one hundred and forty-first meridian of west longitude, from 50 to 100 miles north of Porcupine River, along what is generally considered to be the eastward extension of the Endicott Mountains, there are widespread limestones of lower Carboniferous age overlying an extensive series of quartzites and slates which if more thoroughly metamorphosed could easily be the counterpart of at least a portion of the Birch Creek schist of the Koyukuk-Chandalar region. The Ordovician, Silurian, and Devonian limestones that occur along Porcupine River are apparently absent to the north, in this area. To the west, in the lower and central portions of the Noatak Valley, occurs a series of limestones that is definitely known to be of Carboniferous age, and in the upper Noatak, Kobuk, and Alatna valleys limestones which may be of this general age occupy wide areas. The age of these limestones may be the same as that of the Skajit formation on John River and of the Bettles "series," which crosses the upper Koyukuk and Chandalar basins. It may be that the undifferentiated limestones of the upper Noatak, Kobuk, and Alatna valleys, which have a strong resemblance to the Skajit formation, and which in turn may be the same as the Bettles "series," are not only equivalent but of Carboniferous age. At least, for the present there can be no objection to entertaining this tentative correlation.

MESOZOIC ROCKS.

GENERAL FEATURES.

Sedimentary formations of Mesozoic age do not cover extensive or widely distributed areas in the Koyukuk-Chandalar region. The only sediments definitely assigned to this era are of Cretaceous age and occupy but a small part of the region, being confined to the northeastern part of the central Koyukuk Valley. (See Pl. V, in pocket.) With these sediments are included some basic effusive and pyroclastic rocks that are apparently more or less interbedded with the stratified deposits and are for this reason presumed to be of the same age.

In addition to the Cretaceous sedimentary and basic effusive igneous rocks, practically all the acidic intrusive granitic rocks of the Koyukuk-Chandalar region, which are especially abundant in some parts of the Birch Creek schist belts, as already noted, are considered to have been intruded into the country rocks during Mesozoic time.

CRETACEOUS SYSTEM.

CHARACTER, STRUCTURE, AND DISTRIBUTION.

The unaltered stratified formations of the Koyukuk Valley consist of limestones, sandstones of calcareous, feldspathic, and quartzitic composition, conglomerates, and shales, with some basic igneous effusive and pyroclastic rocks. The feldspathic sandstones or arkoses appear to be characteristic of the lower part of the series and, together with some conglomerates that are probably at or near the base of the series, overlap on the older schistose rocks of the southern foothills of the Endicott Mountains where they meet them along the northern margin of the upper basin of the valley. The limestones appear to characterize the upper part of the series.

All these stratified rocks have been folded and somewhat faulted. The folding is more pronounced at some localities than at others. In some areas the beds are quite horizontal; in others they stand at steep angles. As a whole, however, they have been disturbed far less than the Paleozoic rocks and schists, to which they bear an unconformable relation.

These sedimentary formations occupy the southwestern part of the Koyukuk-Chandalar region and represent the margin of an extensive sheet of Mesozoic sediments which extends south, southwest, and west from the central Koyukuk Valley to Yukon River and Norton Bay. In the Koyukuk Valley they make up practically all the interstream uplands and minor mountain groups between the lower courses of the principal large headwater tributaries of the Koyukuk and the bedrock bluffs along the main river, except in a few places where the older underlying rocks crop out from beneath them.

AGE AND CORRELATION.

The rocks described above have been divided by Schrader[1] into two conformable groups—a lower group, which he named the Koyukuk series, and an upper one, which he called the Bergman series. The lower group contains the marine limestones already noted, which have yielded Lower Cretaceous or Upper Jurassic fossils. The upper or Bergman group, which in part, at least, appears not to be marine and to which the coal beds at Tramway Bar, on the Koyukuk, may belong, has been considered by Schrader to be in-

[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 77–79.

folded and closely related with the Koyukuk group, but to be younger and overlie it. To the south, along Yukon River, sediments of this general character carry both marine and plant fossil remains of late Mesozoic and early Tertiary age which indicate that they were laid down during a period of transition from Mesozoic to Tertiary time, when there was no apparent pause or depositional break in the geologic sequence. For present purposes both the marine and nonmarine groups have been mapped together as Cretaceous.

MESOZOIC (?) INTRUSIVE ROCKS.

The intrusive rocks of the region include granites, granodiorites, diorite, and diabase. All these rocks except the diabase and some of the diorite probably belong to one general epoch of intrusion. Some of the granitic rocks are gneissoid and may be older than the Mesozoic. As has already been said (p. 37), there is no direct evidence of the age of any of these intrusive rocks, though they are known to be, in part at least, younger than the volcanic rocks described in connection with the rocks of probable Devonian age (p. 50), and are probably older than the Mesozoic sediments which have been assigned to the Cretaceous. These igneous rocks, except the diabase, are here assigned to the Mesozoic because that is known to be the era of most widespread intrusive igneous activity throughout Alaska. Moreover, they resemble the known Mesozoic intrusive rocks of other parts of the Territory. Schrader[1] has noted the presence of diorite dikes in the Cretaceous sediments of the middle Koyukuk Valley. It seems probable that some of the diorites or granites may be of later age than the Cretaceous.

Because of the occurrence of rocks of intermediate composition no sharp line can be drawn between the granites and the diorites. The diorites differ from the granites in the predominance of plagioclase feldspars, the subordination of quartz, and the substitution of hornblende for mica. Quartz diorites or granodiorites, of intermediate composition between the diorites and granites, are not uncommon. In the large masses the rock is generally of granular texture, but porphyritic phases occur both within and around the margins of the larger intrusive masses and also in the dikes and small stocks.

On the middle Chandalar and elsewhere in the region some of these intrusive rocks are gneissoid. These are sheared and crushed igneous rocks consisting of quartz, feldspar, mica, and hornblende, with chlorite abundantly developed as a secondary product, giving the rocks a greenish color. They may represent an older epoch of injection than that of the less altered, more massive igneous rocks.

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[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 77.

Among the rocks not included in the foregoing description are some aplite dikes and veins which cut the granites in a few places and probably represent the last stages of igneous activity.

The areal distribution of these intrusive rocks needs no special discussion, as it is shown on the map. Attention may, however, be called to the extensive masses of granite and diorite which occur in association with the Birch Creek schist of the Hodzana highland belt, between the Chandalar and the Koyukuk. Granitic and dioritic rocks also occur in other parts of the field (see pp. 41–43), in addition to which there are many dikes that are unmapped.

CENOZOIC ROCKS.

TERTIARY SYSTEM.

The sedimentary rocks which may with reasonable certainty be assigned to the Tertiary period are known to occur at one locality in the area under consideration. These occupy a very small area (see Pl. V, in pocket) in the upper basin of Dall River, on and near the lower part of a west-side tributary named Coal Creek. They comprise soft gray, buff, or black shales, standing at an angle of about 30° and associated with a heavy bed of lignitic coal and bone. No fossil plant remains have been found in these beds, but because of their lithologic resemblance to well-determined strata in other parts of the Territory, they are considered to belong to the group of Tertiary lignite deposits.

On the Middle Fork of the Koyukuk about 12 miles below Coldfoot the older rocks on the north give way to a series of younger sediments composed of sandstones, grits, and shales, with conglomerates and at least one bed of coal. Schrader,[1] who observed these beds, first considered them to be of Tertiary age, but in a later report[2] named what appear to be the same sediments to the west, on John River, the Bergman "series" (see p. 54) and provisionally referred them to the Cretaceous.

More detailed surveys of this region may disclose other areas of Tertiary sedimentary rocks, some of which may be coal-bearing.

CENOZOIC LAVAS (TERTIARY OR QUATERNARY).

Two areas of lavas which may be of Tertiary age are known in this region, one on Kanuti River and the other on Chandalar River. Mendenhall[3] has described the Kanuti River area as follows:

[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 477.

[2] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 77–79.

[3] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound: Prof. Paper U. S. Geol. Survey No. 10, 1902, pp. 42–43.

Basalt.—Along the middle Kanuti River horizontally bedded vesicular olivine basalts form bluffs 50 to 75 feet high on the north bank of the river, and similar bluffs south of the valley are probaby due to the same formation.

Andesites and tuffs.—The most extensively distributed lavas in the Kanuti River valley are hornblende-andesites and associated fragmental material. They are composed of massive flows and coarse breccias, the latter sometimes containing angular blocks 10 feet in diameter, embedded in fine ash or pumice. They form bluffs 250 feet in height along the river. Downstream from this locality the tuffaceous form of the deposit disappears, but the low hills for many miles north of the river are made up entirely of massive andesites.

Age.—The basalts and andesites were not found in contact, but both occur along the Kanuti River in horizontally bedded flows. The andesites lie at higher levels and are therefore perhaps younger. Since both are structurally undisturbed, they are more recent than the Tertiary lignite-bearing beds of the upper Dall River, which are extensively folded. The relation of the andesites to the topography is such as to suggest that the lavas flowed into valleys which had been cut to approximately their present depth, and this brought about changes in drainage. The streams have since cut through or at least well into the lava and breccia filling and have removed in some cases hundreds of feet of it. This cutting may have occupied all of Pleistocene time but probably not more, so that the lavas are to be regarded as very late Tertiary or possibly early Pleistocene.

On the south bank of Chandalar River from 60 to 65 miles above its mouth, at the point where it enters the Yukon Flats, there is an area occupied by dark olivine basalts. They are principally amygdaloidal, and in part very coarsely porous and weather to a reddish or rusty brown, but they include some layers of more dense texture which usually have a fresh dark iron or steel color. Their attitude is not well exposed, but they appear to have a typical lava flow structure and to consist of superimposed members several feet in thickness. Their topographic expression is that of a plateau or flat-topped bench whose highest parts stand about 1,000 feet above the river. It is not thought that their thickness is as great as 1,000 feet, however, for to the west, about a mile above the East Fork, the lavas are succeeded by gneissoid granitic rocks which are undoubtedly older, and to judge from the talus along the valley slopes opposite and east of the mouth of East Fork the gneissoid rock appears to extend in this direction for several miles as the basement upon which the lavas rest, although the contact of the two has not been observed. The lavas are best exposed in a few bluff faces overlooking the river near the upper edge or break of their benchlike surface. The margins of this bench are not much rounded and are for the most part merely notched here and there by erosion.

The areal extent of these basalts is not known, but if they are the capping formation of the benchlike feature which characterizes each side of the Chandalar Valley, where it opens out into the Yukon Flats, they may extend southwestward for a considerable distance and they may occur on the north side of the valley also.

These basalts, like those on Kanuti River, are provisionally considered to be of late Tertiary or early Pleistocene age.

QUATERNARY SYSTEM.

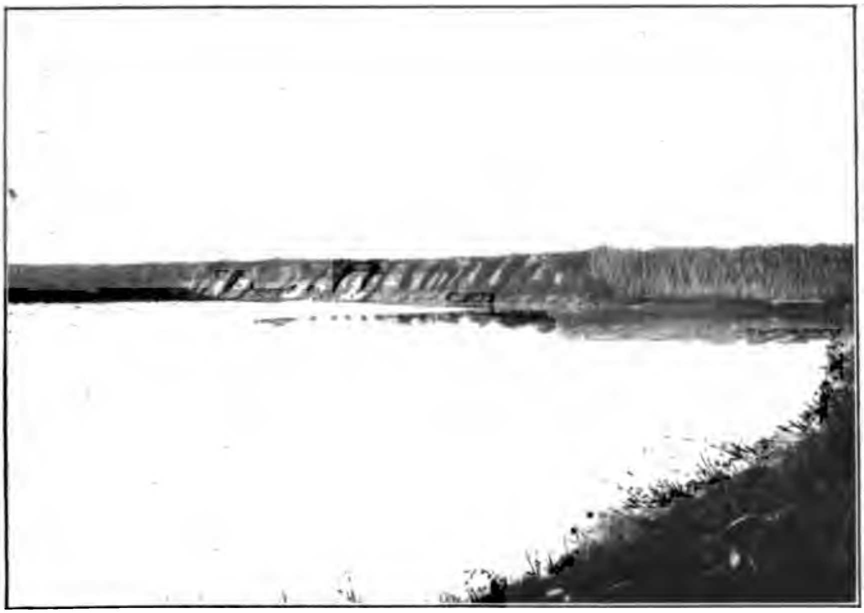
PLEISTOCENE SERIES.

SEDIMENTS.

Extensive deposits of unconsolidated sediments, which for the most part seem to be stream laid, occur along the southern foothills or flanks of the Endicott Mountains and extend southward from them as thick and widespread fillings along all the main drainage courses of the region and also extend across the lower divides from one drainage basin to another. They are without doubt contemporaneous throughout the region and are the result of a system of drainage that was quite different from that of to-day. They are composed of gravels, sands, and silts, and although they show considerable variation in coarseness, their predominant characteristics are that they have been transported, assorted, and deposited by flowing water and appear to be in large part glacial débris or detrital materials which have been vigorously outwashed from the mountains to the north.

The upper South Fork and Mosquito Creek basins are practically filled with these more or less assorted outwash deposits of gravels, silts, and bowlders and they also occupy a wide expanse west and northwest from South Fork for 15 miles to the Middle Fork of the Koyukuk, and beyond, down the valley of that river. From north to south across this area the width of these unconsolidated deposits is about 10 miles. Their general surface appears to slope both from east to west and from north to south. Their highest margin is along the base of the mountains on the north, where they stand at about 2,000 feet, but they seem to descend gradually from east to west to a general elevation of 1,500 feet on the Middle Fork at Tramway Bar. They also slope gradually from north to south at about the same grade, their elevation along the banks of the South Fork 20 miles below the mouth of Mosquito Creek being about 1,500 feet above sea level. However, there are remnants of gravel benches on the mountain slopes south of South Fork which indicate that a former surface of these deposits may have had an even more gentle descent across this area from north to south than the present slope and that the present surface may be due in great part to removal by erosion along the South Fork of a very large quantity of the unconsolidated filling. Likewise erosion by the present streams is, no doubt, the agency that has lowered the surface of these deposits along the Middle Fork.

In fact, the occurrence of these deposits on terraces throughout all the large valleys of the region admits of no other interpretation, for



A. PLEISTOCENE SILT BLUFFS ON KOYUKUK RIVER NEAR ARCTIC CIRCLE.

B. GOLD CREEK VALLEY NEAR MOUTH.

Looking upstream from top of canyon. Shoulders indicate old valley-floor level, now dissected by recent V-shaped valley.

these terraces evidently indicate the elevation and extent of the former flood plain upon which the sediments of the terraces were deposited. It seems that the drainage system which transported and aggraded these unconsolidated sediments over such wide areas must have been of a different character from that of to-day. (See pp. 60–67.)

The present drainage has not only removed a large quantity of the unconsolidated filling and thus lowered and modified its surface and left its marginal portions as terraces or benches, but recently at least its major channels have entrenched themselves into the unconsolidated deposits locally to depths of 100 to 200 feet, and at places into the harder underlying country rocks as well. By far the largest part of the deposits, however, still remain on terraces or sloping benches which extend far up the sides of the valleys and across the low divides that separate many of the lateral tributaries which drain the foothills. These bench deposits are especially to be noted between the Middle and South forks of the Koyukuk from the vicinity of Slate Creek and Tramway Bar eastward, as has been described, and also from the South Fork, by way of Mosquito Creek, to west-side tributaries of the Chandalar named Crooked Creek and West Fork, where the gravels and silts extend across divides that stand at elevations of 2,350 feet.

They occur on extensively developed terraces along the North, Middle, and East forks of the Chandalar and are continuous with similar deposits along the main river that extend downstream to the northern margin of the Yukon Flats, where the highest terraces stand at elevations of about 1,500 feet above sea level. Likewise they extend southward along the valleys of the Middle Fork and main Koyukuk (Pl. VII, *A*) to the northern edge of the Koyukuk Flats, where they merge with the marginal basin deposits at an elevation of about 1,500 feet, about the same as those of the Yukon Flats.

The terrace deposits along the south front of the Endicott Mountains extend northward up the main valleys within the mountains, decreasing in lateral extent as the valleys become narrower and increase in elevation. On the Middle Fork of the Koyukuk at the mouth of Wiseman Creek they stand at an elevation of about 2,500 feet and farther north, within the mountains, they rise to about 3,000 feet on upper Bettles and Dietrich rivers.

Near the mountains the deposits contain glacial bowlders, and these are more numerous within the mountain valleys, where, in general, the deposits bear more resemblance to a glacial valley filling, as they contain much coarser material which in places does not show marked assortment or arrangement by running water. There are also scattered patches of what appears to be glacial till and a few bowlder trains that have a morainal aspect. In general the coarser materials are characteristic of the mountainous part of the region,

while to the south, beyond the mountains, the deposits are more commonly composed of fine silts.

What has just been said in regard to the Middle Fork within the Endicott Mountains applies also to the other branches of the Koyukuk and to the Chandalar and its principal tributaries. For example, these deposits stand at an elevation of approximately 3,000 feet in the depression drained by Lake and Grave creeks, and gradually descend and coalesce with the terrace deposits of the North and Middle forks of the Chandalar.

These terrace deposits were wholly or in large part intimately associated with the retreat of glacial ice and can probably be best classed as outwash deposits. Whether the silt deposits of the Yukon and Koyukuk flats are also of glacial origin has not been definitely determined. They may be in part, at least, of such derivation.

In several localities, notably at Tramway Bar on the Middle Fork and Gold Bench on the South Fork of the Koyukuk, gold-bearing gravels are closely associated with the terrace deposits. These gravels, however, are probably of local origin, as will be described under gold placers (pp. 85, 106). The nature of the terrace gravels does not seem to favor the probability of their being gold-bearing except where they have been locally reconcentrated since their deposition, and even so only where there are sources near by from which the gold might be derived.

All the unconsolidated sediments which occur in terraces or sloping benches above the flood plains of the present streams together with the glacial till and morainic deposits within the mountains of the northern part of the region, are considered to be of Pleistocene age.

GLACIATION.

The Endicott Mountain belt bears every evidence of having been subjected very recently to the erosion of glaciers across its entire width of 80 to 100 miles. To judge from the form, length and arrangement of the present valleys which dissect the mountains across their trend and which appear to owe their present deep, narrow forms largely to the erosion of ice streams, it seems that the dividing line from which the former glaciers moved to the north and south was along a zone of maximum snow accumulation whose position corresponded to the present Arctic-Yukon watershed, which lies nearer to the northern flanks of the mountain belt than to its southern flanks, and that the southward-flowing ice streams were probably longer, at least within the mountains, than those that moved northward. By far the largest part of this mountainous belt has not yet been explored. From the meager data at hand it is impossible at this time to present a satisfactory discussion of the glaciation of this part of Alaska.

Schrader is the only observer who has described the extent and character of glacial erosion and deposition along a section that crosses these mountains. His observations were made from the Koyukuk Valley to the Arctic coastal plain by way of John and Anaktuvuk rivers, along the western edge of the area now under consideration. In a concluding paragraph [1] he summarizes as follows:

The glacial phenomena that have been described tend to show that, although the Endicott Mountains do not on the whole seem to have been overridden en masse by a moving ice sheet, they were doubtless, especially in their northern part, largely occupied by an ice cap or perennial névé, constituting a breeding ground for glaciers. The zone of maximum snowfall, and consequently of maximum ice accumulation, trending in an east-west direction, was apparently in the northern part of the range, at least somewhat north of its median line. From this zone the ice moved off to the north and to the south, respectively, into the Colville and Koyukuk basins. Its flowage, especially during the latter part of the ice age, was confined mainly to the valleys and drainage ways in the form of alpine glaciers, of which there is ample evidence. But there is also good reason to believe, as shown by the till sheet north of the mountains, that during the zenith of the ice age the northern edge of the range was occupied by a more or less extensive ice sheet, which, as a small regional or piedmont glacier, thinning out toward the north, extended northward over a considerable portion of the Anaktuvuk Plateau, its occurrence at that time being, perhaps, similar to that of the Bering and Malaspina glaciers of to-day [on the Pacific seaboard of Alaska].

It is presumed that the glaciation of the Endicott Mountains eastward from John and Anaktuvuk rivers, where Schrader observed its results, was similar throughout that part of the region occupied by the headwaters of Koyukuk and Chandalar rivers. It is known that on the sources of Canning River, which lies opposite the upper East Fork of Chandalar River, a few small mountain valley glaciers still exist, and that farther eastward, about 50 to 75 miles west of the 141st meridian, a group of mountains from 8,000 to 9,000 feet high carry some large glaciers. From the presence of these ice bodies it seems fair to surmise that glaciers of considerable extent remained in these mountains up to comparatively recent time.

At the time of the maximum development of the ice the glaciers which occupied the larger valleys evidently extended for some distance from the mountain front both to the north and to the south. On the north front of the Endicott Mountains, along the rims of the Anaktuvuk Valley, where it cuts across the Anaktuvuk Plateau, Schrader found evidence that the ice overflowed the valley and spread out over the plateau as piedmont ice sheets. This plateau surface, as it extends east and west along the front of the mountains between the larger valleys which cross it from south to north, was evidently overridden by an ice sheet that apparently completely

[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 91.

covered the interstream areas. At least unconsolidated deposits of glacial drift are spread over this surface as a more or less continuous covering up to elevations of 2,500 to 2,600 feet above sea level.

On the south front of the Endicott Mountains in the Koyukuk-Chandalar region there are no pronounced physiographic interstream features corresponding to the Anaktuvuk Plateau. There is, however, a broad, flat divide between the upper South Fork of Koyukuk River and the Chandalar whose highest parts stand at about the same elevation, 2,500 to 2,600 feet, as the surface of the Anaktuvuk Plateau, and deposits of glacial débris occur on this divide. These deposits of glacial detritus extend southward from the mountain front for about 15 miles, or to the northern edge of the Hodzana highland, and it appears that they were laid down there by a piedmont ice sheet which probably covered the whole area from east to west between large valley glaciers that moved out from the mountains along the present courses of the Chandalar and the Middle Fork of the Koyukuk.

Schrader[1] considers that the ice mass which evidently occupied the Koyukuk Valley may have extended as far south as the mouth of Kanuti River, or about 50 miles from the mountain front. The evidence he cites in support of this view is that the Koyukuk Valley region exhibits a generally rounded topography, suggestive of former glaciation, up to a height of 1,600 or 1,800 feet; that till-like deposits occur near the mouth of John River and on the west bank of the Koyukuk between Bettles and the mouth of Jane Creek, where they form bluffs about 100 feet high; that on the northeast side of the lower Alatna Valley what seem to be till terraces occur along the south side of Double Mountain up to a height of 1,600 feet; that just below the mouth of Alatna River there is a steep-faced exposure of clay and gravel, standing from 80 to 100 feet above the river, the lower 50 feet of which seems to be glacial till; and that from the character of the topography glacial drift is suspected to occur along the east bank of the Koyukuk southward from the Alatna toward the mouth of Kanuti River.

From the above-enumerated observations in this part of the field it is inferred that glaciation extended from the Endicott Mountains southward into the Koyukuk basin across the Arctic Circle and beyond Bergman.

In that part of the Chandalar Valley which borders the northeastern margin of the Hodzana highland from the Yukon Flats to the West Fork there occurs a more or less continuous series of terraces and sloping benches of unconsolidated Pleistocene deposits which form bluffs along the river 100 feet high. Schrader considered

[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 89.

some of this unconsolidated detrital material to be glacial till. He also observed glacial drift on the south side of this valley, opposite the mouth of Flat Creek, at a height of about 2,200 feet, approximately the height at which similar deposits occur along the north flanks of the Hodzana highland to the west. From the above meager facts it may be provisionally suggested that the Chandalar Valley was occupied by a large glacier which extended nearly, if not quite, to the northern border of the Yukon Flats.

To summarize briefly, it appears that at the time of their maximum extent glaciers extended southward along the larger valleys for some distance from the mountain front, probably at least 50 and possibly 100 miles or more, and that the areas along the mountain front within 15 or 20 miles of and between these large valley glaciers were covered by piedmont ice sheets up to an elevation of about 2,500 feet. Taking 2,500 feet as the approximate upper limit of glaciation just beyond the mountain front, it may be stated that in general the surface of the ice rose from south to north and probably had an elevation of 5,000 or 6,000 feet on the mountains along the zone of supply, in the general position of the present watershed.

Apparently all the trunk valleys across the Endicott Mountains have been modified by glacial erosion and have been more or less filled with products deposited as the glaciers wasted away and disappeared. The after effects of glaciation are shown in various ways within the mountains, principally, however, by the deposits along the valleys which have already been described (pp. 59–60). Some of the special features they present, which are of economic interest because of their association with gold-bearing gravels, will be noted.

The surface of the region is predominantly one of bold mountainous character, whose principal features are rugged ranges, with general structural trends from northeast to southwest, and deep, but comparatively narrow, steep-sided valleys cut through the mountains by the larger rivers from north to south. The bottoms of the larger valleys are from 1,500 to 2,000 feet above sea level, and from a quarter of a mile to 2 miles wide. The mountains rise boldly and in places abruptly from valley bottoms to rugged heights from 2,000 to 5,000 feet above the valleys, or 3,000 to 6,000 feet above sea level; indeed, along the major divides some peaks rise to elevations of nearly 7,000 feet.

The most marked features of the drainage are a north-south system of narrow, parallel major valleys deeply incised into the mountainous land mass, and an immaturely developed lateral drainage on the flanks of the mountain divides that separate the larger rivers. The downcutting along the larger valleys has been so rapid during the comparatively recent geologic history of this region that most of the drainage of secondary magnitude lateral to the rivers has not

been able to extend the areas of the tributary valleys, or wear them down to the level of the principal valleys, the result being that most of the creeks on which placer mining is done are rather swift, and have steep-gulch valleys, and in many places box canyons along their courses, especially in their lower parts, just before they join the larger valleys. Much of the placer gold mined has been taken from the comparatively narrow and shallow gravel deposits along the bottoms of these tributary valleys.

The main valleys appear to owe their present size and forms chiefly to the former presence of large, long glaciers that had their sources on the Arctic divide to the north, and extended at least to the southern flank of the Endicott Mountains. The large ice streams appear to have modified the shape of the cross sections of the main valleys by cutting away their lower slopes, and thus widening their floors somewhat and steepening them to the forms they have to-day, which are characterized by flat bottoms and abruptly rising sides. These steep sides are especially pronounced where formed by the truncated ends of the intertributary mountain spurs that are lateral to the main divides. In places these steeply truncated sides of the main valleys extend across the mouths of the tributary valleys, thus making them of the hanging-valley type. In most such places the streams in the discordant side valleys have partly cut their immediate channels down below the old floor levels of the hanging valleys, and now enter the main valleys through gorges or canyons (Pl. VII, *B*, p. 58). Other side valleys, however, enter the main valleys by wide mouths at accordant levels.

When the large glaciers disappeared by melting, they left behind considerable quantities of unconsolidated material in the form of bowlders, cobbles, gravels, and silts, which now largely cover the floors of the valleys throughout their length and width. Very little of this material is now found in the form of unassorted drift. Most of it belongs to the class of glacial deposits that have been subjected to the vigorous wearing and assorting action of swiftly running water after the glaciers retreated. Along the flat lower parts of the valleys these deposits have been well graded and now occur in the form of partly sorted cobble beds, regularly arranged gravels, coarse cross-bedded sands, and fine silts and clays. They occur not only along the floors of the large valleys, but also as terraces along their sides and back into the tributary valleys that open out from the mountains. In the middle part of the Tobin Creek valley and on lower Big Creek there are thick deposits of silt and clay which appear to have been deposited in small lakes that were formed along the borders of the glaciers in the lower parts of these side valleys at a time when the main valley glaciers dammed up their mouths with high barriers of ice. Most of the silts and clays of the dammed valley deposits appear

to have been derived from muddy glacial waters, but no doubt some of the silts may have come from the upper parts of the side valleys above the areas formerly occupied by the lakes, and also from the slopes that were above the levels of the lakes along their sides. Wiseman Creek, on the Koyukuk, occupies one of the best examples of these glacier-dammed and silt-filled valleys, where the silts and clays have buried older gold-bearing stream gravels and where the later drainage has not been able to remove the glacial silt and clay filling. Tobin Creek is an example of a filled valley where the present drainage has been vigorous enough to remove a large part of the clays and is now rapidly carrying away what remains. This is shown by the turbid silt-laden water of this stream from the "mud banks" to its mouth. The lake that formerly occupied the basin of Wiseman Valley was apparently drained by several comparatively sudden drops to lower levels, with longer periods of rest between the drops. During the stationary periods bench deposits, or narrow beaches, were formed on the valley slopes at the positions of the different shore lines of the lake and the gold now found in these benches along the valley sides was no doubt concentrated in them at the mouths of gulches. The gold appears to have come from the bedrock of the mountain slopes above the lakes, and no doubt much of the gold now found in the benches at the lower levels is derived from similar benches at higher levels where gold was concentrated previously.

On Tobin and Big creeks, in the Chandalar Valley, the old shore lines of the former lakes have not been traced or prospected and it is not known whether they occur at more than one level. On Wiseman Creek, in the Koyukuk Valley, the former glacial-lake shore lines are known to lie at several different levels. These have been prospected to a slight extent and the two lowest have been mined at several places along the east side of Nolan Creek. Placer gold is reported to occur on Tobin Creek, both below and above the locality where the stream is now washing away the clay deposits of the former glacial lake that occupied the lower half of its basin, but paying quantities have not yet been developed.

As a result of this varied relief and its modified forms the unconsolidated deposits of the valleys, whether gold-bearing or not, present many different features of character, position, depth, distribution, and condition. In some localities the erosion and deposition accomplished during a former period of drainage development, which appears to have been largely the result of glacial conditions, seem to be responsible for the present nature of the placer-gold deposits, whereas at other localities glacial drainage does not appear to have effected the processes of erosion or the concentration of the gold, which appear to be such as are normal to an unglaciated moun-

tainous region. For example, the influence of a former glacial drainage does not appear to have extended to the part of the Chandalar district at the head of Big Creek, where most of the mining development has been carried on, nor to some of the streams in the Koyukuk district, such as the upper parts of Myrtle, Vermont, and Gold creeks. On the other hand, the valley of Wiseman Creek and its gold-producing tributary, Nolan Creek, in the Koyukuk district, appears to be an example of a preglacial valley where older gold-bearing stream gravels have been buried beneath silts and clays, probably derived from ponded muddy glacial waters, which the erosion since that time has not removed. The result is that the gold-bearing deposits of Nolan Creek are mined by means of shafts from 40 to 80 feet deep sunk through silts and clays to the buried gravels in the bottom of the bedrock valley. The placer gold in lower Hammond Creek valley appears also to occur in gravels that were deposited along the bottom of a preglacial stream bed which is now filled to the depth of 100 feet or less by later outwashed glacial sediments.

RECENT SERIES.

The sediments of Recent time include all the unconsolidated deposits that have been laid down along the present drainage courses and that are not considered to be of Pleistocene age. By far the most of the unconsolidated sediments of this region are assigned to the Pleistocene—that is, they are thought to have been laid down during the epoch immediately preceding the present one, when the drainage conditions were somewhat different, as outlined in the preceding section. As there stated (pp. 58–59), most of the Pleistocene sediments occur in terraces and sloping benches that stand from 50 to 1,000 feet above the flood plains of to-day. In general the present drainage system is cut down into the Pleistocene deposits, especially along the larger trunk streams, many of which flow at the bases of bluffs of unconsolidated sediments 100 feet and more in height. Most of the Recent alluvium is derived from these older unconsolidated sediments. The primary difference between the Pleistocene and the Recent deposits is that of position rather than of kind, and even in this regard the two are in places so intimately related by intergradation that it is difficult to separate them with satisfaction. For the most part the Recent sediments do not stand much above the flood plains of the present streams. As a rule benches of Recent silts or gravels are not more than 20 to 30 feet above the ordinary level of the streams which have laid them down.

In the larger valleys, however, where the flood plains are wider and where basins have been silted up recently, the latest deposits

show other differences than those of position alone. They vary in composition, the Recent sediment being for the most part of a darker color than the older unconsolidated sediments with which they are closely associated at many localities, and the darker color appearing to be due to the larger proportion of vegetable matter mixed with them. The vegetable matter in the Recent silts is apparently derived in large part from the peat deposits which lie mostly on top of the silts, but which are also at many places interbedded with them. In fact, it appears that the peat derived from the heavy growth of sphagnum mosses over all the swampy lowlands may be considered the most characteristic and widespread of Recent deposits. Peat beds several feet in thickness, interbedded with the silts, are exposed repeatedly along the low-cut banks of many of the larger streams. There are also some lenticular beds of ice exposed along the cut banks, and considerable of this "flood-plain ice" is deposited throughout the Recent alluvial lowlands. Where the rivers flow through lowlands the banks exhibit in many places alternating vegetable and silt layers, the former generally the more prominent. Associated with both there are scattered bowlders and embedded gravels, which are regarded as ice-borne. The surfaces of the flood-plain lowlands bear numerous ponds and lakelets, many of the latter being of the oxbow or abandoned-channel kind.

Immediately along the larger streams the bars of gravel and sand are the most characteristic deposits. These are naturally best developed on the inner sides of the wide curving bends of the larger rivers. Along the accordant drainage courses south of the Endicott Mountains such deposits are practically continuous, for at times of flood, especially in the spring, the rivers spread over valley floors, some of which are a mile or more in width, and deposit upon them a considerable sheet of gravel and detritus, a large part of which is exposed when the streams fall to their more normal stages.

Within the Endicott Mountains, where much of the lateral drainage is discordant with the trunk streams, the recently laid stream deposits are more or less disconnected and do not have well-adjusted gradients. Recent stream gravels at some places stand, as benches, at higher elevations above the streams that have deposited them than is usual south of the mountains. Alluvial fans are commonly developed at the mouths of tributary streams where they empty into the wide valleys of the larger rivers. In general the Recent stream deposits within the mountains are composed mostly of gravels and coarser detritus, and banks of silts and vegetable matter are not so common. The gold-bearing gravels and silts associated with them will be described in more detail in connection with the particular localities where prospecting and mining has been done. (See pp. 84–108.)

MINING.

PRODUCTION.

Since placer gold was found in 1899 on Myrtle Creek, a tributary of Slate Creek, successive discoveries have been made on other tributaries of the Koyukuk, with the general result that the yearly production has steadily increased during the last 10 years, the newer finds more than compensating for the decreasing yield of the older placers.

The production of placer gold in the Koyukuk, though not so large in amount as that in the Nome and Fairbanks districts, has been noteworthy when its difficulty of access and small population are considered and has probably averaged higher per capita than that of any other district in Alaska. Since the discovery of the district its development has been practically accomplished with only its inherent mineral resources to aid mining enterprise, there having been, with one exception, no exploitation by capital from without the district. In other words, the Koyukuk stands as an entirely self-supporting mining community.

Schrader[1] has published a table of production of gold for the Koyukuk district for the period from 1900 to 1903, based on the most reliable information he could obtain. The writer has endeavored to extend this table to the close of 1909 (p. 69). Schrader's table gives a total of $667,500. To this he added $40,000 as the approximate output of sundry smaller diggings not given in the list for 1901; $6,000 as the output in 1899, derived mostly from Myrtle and Slate creeks and various places on South Fork; and $3,000 to $4,000 from Tramway Bar bench and river bars in previous years, all of which gave an aggregate yield for the district to that date of about $717,000. The revised and enlarged table presented here gives an approximate total production of $2,200,600 for the 10 years 1900–1909. Up to 1909 the output of the year 1903 appears to have been the largest. This is easily accounted for by the facts that the shallow diggings were then at their best and that the very easily mined gravels on Mascot Creek yielded about $100,000 during that summer. After 1903 there were several years of gradual decline in production, which appears to have reached its lowest point in 1906. The low yield for 1906 is partly explained by the rush to the new Chandalar placer district, about 75 miles east of Coldfoot, in August of that year, which took a number of men from productive work in the Koyukuk a month before the summer mining season had closed. From 1906 to 1909 there was an increase of production each year which was derived largely from the deep placers on Nolan Creek.

[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 102.

There is some uncertainty in assigning the figures of production since 1906 to separate calendar years, because the underground mining operations extend from one year into the next and the figures given for a particular claim cover parts of two years. In the table the production of Nolan Creek for 1908 and 1909, which has been the largest factor during these two years, has been arbitrarily divided; but it is thought that if the statements obtained as to the yield are reliable the totals are good approximate estimates, and that the table as a whole is as fair a summary as it is possible to present from the information at hand.

The gold production of the Koyukuk district declined during 1910 and 1911, amounting to approximately $160,000 for 1910 and $140,000 for 1911. During 1912 there was an increase over the two previous years, about $200,000 being the estimated yield. As detailed information is not at hand for apportioning the output for these three years to the various creeks, no attempt has been made to extend the table. However, probably 75 per cent of the gold output for these three years has been produced from the deep mines on Nolan Creek and new workings of deep gold-bearing gravels in the lower valley of Hammond Creek that have been developed during 1911–12. It is thought that the increase for 1912 may be chiefly credited to Hammond Creek.

As thus estimated the total placer-gold production of the Koyukuk district up to 1912, inclusive, is about $2,700,000.

Estimated production of placer gold in the Koyukuk district from 1900 to 1909, by localities and years.

Locality.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	Total.
Middle Fork:											
Tramway Bar	$5,000								$300		$8,000
Twelvemile Creek	1,000	$1,500									5,000
Porcupine Creek	500	1,000									2,000
Slate Creek	1,000										3,000
Myrtle Creek	40,000	7,000	$50,000	$30,000	$15,000	$15,000	$5,000	$5,000	$5,000	$10,000	182,000
Clara Gulch	1,000	2,000									3,000
Kelly Gulch		500									500
Marion Creek											1,000
Emma Creek	27,000	40,000	13,000	15,000	10,000	15,000	5,000	5,000	5,000	5,000	160,000
Nolan Creek					14,000	40,000	90,000	125,000	208,000	288,000	765,000
Smith Gulch				25,000	30,000	50,000	10,000	5,000	5,000	83,000	208,000
Archibald Gulch					2,000	2,000					6,000
Fay Gulch				3,000	20,000		3,000			2,500	30,000
Minnie Creek					500		400				1,000
Union Gulch		1,500	30,000							2,000	35,000
Hammond Creek	2,000	2,000	10,000	2,000	2,000	2,000					20,000
Goldbottom Gulch			6,000	2,000	2,000						10,000
Swift Gulch			3,000	2,000	1,000					1,200	7,200
Buckeye Gulch					1,000	200					1,200
Vermont Creek		5,000	30,000	25,000	22,000	20,000	20,000	20,000	10,000	20,000	172,000
Sheep Creek								500	1,000	500	2,000
Gold Creek	2,000	50,000	30,000	70,000	45,000	24,000	3,000	3,000	2,200	3,000	232,200
Linda Creek			8,000	10,000				400	300		20,000
Bettles River:											
Emory Creek										1,000	10,000
Garnet Creek											1,000
Mule Creek							300				1,000

Estimated production of placer gold in the Koyukuk district, etc.—Continued.

Locality.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	Total.
South Fork:											
Gold Bench	$25,000	$60,000	$20,000	$15,000	$5,000						$125,000
Ironside Bench	500										2,000
Grubstake Bar	1,500	1,500									4,000
Eaglecliff Bench	500										1,000
Davis Creek											5,000
California Creek		1,000									3,000
Jim Gulch		500							$1,000	$1,000	3,000
North Fork:											
Mascot Creek				100,000	25,000	$20,000					145,000
Washington Creek				2,000	2,000	1,000					5,000
Wild River:											
Birch Creek						5,000	$5,000				10,000
Lake Creek					1,000	1,000					2,000
Spring Creek								$5,000	1,000	1,000	7,000
John River: Crevice Creek					2,500						2,500
	107,000	173,500	200,000	301,000	200,000	195,200	141,700	168,900	238,800	418,200	2,200,600

The results of mining as summarized above have been accomplished by an average of 100 men a year who have actually worked at mining. Some men have left the district each year, but others have come to replace them. If the average cost of production is placed at about 50 per cent of the total yield, about $1,350,000 may be considered the amount of wealth that has been taken away from the Koyukuk district during its mining development by those who have become satisfied with their gains and have departed from Alaska for "the outside with a homestake," as it is called in that country.

The Koyukuk placer gold is of a high grade. Its refined value varies from $18 to over $19 an ounce. The unrefined gold has passed in commercial exchange at $17 an ounce until 1909, when it was allowed a value of $18 an ounce.

The subjoined table gives an estimate of the production of both gold and silver from 1900 to 1911:

Estimated production of placer gold and silver in the Koyukuk district from 1900 to 1911.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1900	5,176.13	$107,000	310	$192
1901	8,393.06	173,500	503	302
1902	9,675.00	200,000	581	308
1903	14,560.87	301,000	874	480
1904	9,675.00	200,000	580	286
1905	9,442.80	195,200	567	346
1906	6,854.74	141,700	411	280
1907	8,170.53	168,900	490	323
1908	11,551.95	238,800	693	367
1909	20,230.42	418,200	1,214	631
1910	7,740.00	160,000	464	250
1911	6,772.50	140,000	406	215
	118,243.00	2,444,300	7,093	3,980

METHODS OF MINING.

SURFACE MINING.

Shallow placer mining can be most economically conducted by excavating some kind of opening into the natural surface of the deposit and removing all the material associated with the gold down to the real or " false " bedrock, upon which most of the gold generally rests. The methods of moving the unconsolidated material are many—hand shoveling, ground sluicing, hydraulicking, horse or steam scraping, steam shoveling, derricking, and dredging, singly or in various combinations. Where the more efficient mechanical means, such as steam shoveling or dredging, are employed for moving the gravels from open surface excavations, placer deposits 40 feet or less in depth may be termed shallow and, if frozen, may be thawed artificially to this depth to facilitate the operation of heavy excavating machinery. If the deposits are treated by ground sluicing or hydraulicking with plenty of water, the thawing of frozen ground may sometimes be accomplished to this depth as the excavating progresses. But as soon as the depth increases beyond a point where the deposits can not be worked profitably by surface excavating methods they merge into the class of deep placers. Whether any particular deposits may be properly called shallow or deep placers depends upon the method of working employed, for the two classes may overlap.

In the Koyukuk only the methods of hand shoveling, ground sluicing, and hydraulicking have been used up to the present time. Hand shoveling, sometimes in combination with a little ground sluicing, in the shallow unfrozen stream and bench gravels less than 6 feet deep, has been the method by which most of the gold has been mined in this district. Six feet may be considered about the limit of depth of shallow unfrozen ground that may be mined profitably by hand shoveling, and deposits of this kind are naturally the best suited for immediate development by men whose principal capital is hardihood and a willingness to work. Consequently these shallow placer deposits are the kind most sought for, because they yield the largest returns for the least apparent investment of time and capital. There appears to be little doubt, however, that the crude manual methods it has been necessary to employ in this district up to the present time are expensive and have failed to save all the gold originally in the gravels, and that there are considerable deposits of shallow gold-bearing gravels that can never be worked successfully by pick and shovel but may be mined with hydraulic equipment. So far the only hydraulic plant is the one on Myrtle Creek (pp. 88–89).

UNDERGROUND MINING.

Deep mining is the kind that is carried on beneath the ground without changing the surface configuration. This method is adapted

for mining deposits in which the valuable strata are so deeply buried under barren material that they can not be mined successfully by any kind of open surface works. Deep gold-bearing deposits are the most distinct class of placers, because they can be practically worked by only one method of mining. This method consists in sinking shafts down to the gold-bearing strata and mining these beds out by lateral drifts, or, if the deposit is a favorably situated thick bench, by carrying drifts alone into the deposit along the gold-bearing beds. As these deposits are generally solidly frozen in northern Alaska, the usual practice is to thaw them by the use of steam. Such operations have been extended to depths of 200 to 300 feet. Owing to the generally frozen condition of the thick unconsolidated deposits the method of mining the deeply covered placers they contain is practically the same throughout Alaska. The necessary machinery for this class of placer mining, with various local improvements suggested by experience, has been well perfected in the Fairbanks and Nome districts during the last 10 years, and these towns are the centers of supply for such machinery for Alaska. The equipment consists of a suitable-sized steam boiler and hoist, small and light for prospecting and larger for regular mining, together with steam pipes, pieces of steam hose, fittings, and a supply of strong hollow bars about 6 feet long provided with steel points at one end and a pounding head at the other for driving into the frozen ground to introduce the steam.

The Koyukuk district, being difficult of access, is not well provided with this kind of equipment. The supply there at present is not only inadequate but poor and expensive. Most of the boilers are patched-up makeshifts. Pipe, hose, and fittings are scarce, and the prices asked for them are unreasonable. Because of this unsatisfactory commercial condition, the method of prospecting with steam boilers and hoists has not been used systematically on the deep gravel deposits. Productive mining of this kind has been carried on, but these operations are confined principally to about half a dozen claims on Nolan Creek, one claim on lower Vermont Creek (pp. 93, 96, 98), and the valley of Hammond River, of which Vermont Creek is a tributary.

COSTS AND WAGES.

It is impossible to give a detailed analysis of the commercial mining status of the Koyukuk district, because direct evidence in the form of actual figures from books is not available, but from general information the principal features may be outlined.

All the goods consumed by the residents of this district, with the exception of a very small amount of game and fish procured locally, are brought from the States, and the freight charges alone for delivery at the mining localities are from 10 to 20 cents a pound.

Prices in 1909 were considerably below the average for the previous 10 years as a result of recent competition in the commercial enterprise of the district. Likewise the present scale of wages is considerably less than it has been during the past, and no doubt if accurate figures could be obtained they would show that the high retail prices of provisions have directly controlled the scale of wages. The amount of supplies available has had considerable influence on prices. On a number of occasions a shortage of some articles has occurred in spite of the high prices asked, and 1909 was the first year in the history of the district in which a satisfactory amount of provisions was in stock at the mining settlements when summer transportation on Koyukuk River closed.

Very few miners in this district keep good records of costs of operation, and it is difficult to obtain accurate statements of the yield of gold, so both have to be approximately estimated in order to make comparisons.

The annual cost of proper food and clothing for the average prospector or miner in 1909 was about $1,000. Ordinary manual labor at present is paid from $4 to $6 a day, with food. The cost of food per man varies from $3 to $5 a day, according to the cost of transporting provisions from the settlements to the places where mining is being done. Before underground mining was developed on Nolan Creek, in 1906, there was little demand for day labor, and when men were employed for a period of time the usual wage was $1 an hour, without board; but a large part of the mining, especially the shallow shoveling kind and considerable of the deep mining, is done by groups of men who enter into partnerships and work on shares.

Under present commercial conditions only the richest placers of this district yield returns that are considered an adequate reward. A few of the most profitable operations are stated to have been conducted with a profit of 70 per cent of the gross yield of gold, or at a cost of 30 per cent of the production. These results, however, have been obtained only in a few localities of the richest deep ground on Nolan Creek and in the most easily worked shallow unfrozen ground, notably on Mascot Creek. Most of such opportunities have been short lived, and a large part of the mining has been done with a relatively low percentage of profit, so low in many instances as to furnish no more than a bare living under the harsh conditions of climate and isolation that characterize this region, where only the optimism that is the predominant characteristic of the gold-seeker's temperament serves to stimulate many of these men to continued effort from year to year.

ECONOMIC GEOLOGY.

GENERAL CONDITIONS.

In the Koyukuk district the only mineral of present commercial value is placer gold. So far as known to the writer no lodes carrying gold in commercial amounts have been found in the district and little bedrock prospecting for such deposits has been done.

Little evidence of the presence of promising veins of quartz is to be seen on the moss and turf covered mountain slopes, and where vein quartz is exposed or indicated by talus fragments along the higher bare ridges or in the stream cuts it is for the most part of the barren unmineralized kind commonly called "bull quartz." Veinlets of quartz containing free gold and pyrite have been found occasionally, but these are usually less than an inch thick and only a few feet long and, so far as known, are so irregular and scattered as to be of no value for lode mining. Nevertheless the probability of the occurrence of workable gold-lode deposits in the Koyukuk district can not be said to be wholly unfavorable. In the absence of actual lode discoveries the only suggestion that can be offered as to the most likely areas is to call attention to the distribution of gold gravels along certain streams where all the evidence points toward the probable derivation of the placer gold from the bedrock of the areas in which such streams have eroded their drainage basins. On the assumption that the gold has its bedrock source in some mineralized form within such areas it is desirable to examine them thoroughly enough to determine the presence or absence of mineralized veins or stockwork zones of workable dimensions.

A good illustration of such an area is afforded by a mountain mass about 4 miles square bounded by Middle Fork of Koyukuk River on the east, Hammond Creek on the north, Vermont and Nolan creeks on the west, and Wiseman Creek on the south, within which the gravels of nearly all the gulches contain more or less placer gold. It appears to the writer that the placer gold of Nolan Valley, which flanks the southern half of the western slopes of this area, has been largely if not entirely derived from gravels that have been washed into the valley from the tributary gulches along the east side. The most important of these gulches, named from south to north, are Smith, Archibald, Fay, and Webster; these, together with several unnamed gulches, have their basins eroded from the southwest portion of the mountain area defined above. Likewise the gold-bearing east branch of Vermont Creek is eroded from the northwest part of this mountain mass. On its north flank, between Vermont Creek and the Middle Fork, where this same mountain area forms the steep southern side of the lower valley of Hammond Creek, it is dissected by several gulches, the larger of which are named, from west to east,

Buckeye, Swift, and Goldbottom. The gravels of these gulches contain more or less placer gold, which is undoubtedly derived from the bedrock of the mountain mass to the south out of which they have been eroded. Like the gulches tributary to Nolan Valley already mentioned, these gulches appear to be the feeders that have supplied most of the gold now found in the deep gravels of Hammond Valley. The east side of this area is dissected by Confederate, Union, and several smaller gulches which discharge into the Middle Fork. Both Confederate and Union gulches contain workable gold-bearing gravels.

To summarize, it may be stated that the gravels of practically all the larger gulches that are eroded into the bedrock of the mountain mass under consideration contain placer gold. It is not uncommon to find pieces of unworn angular quartz in the gravels of these gulches with rough vein gold attached to or embedded in them. A few veinlets of quartz containing free gold and pyrite are known to occur in place and a phyllite schist member of the bedrock of this area is mineralized with gold-bearing pyrite. There is no doubt that gold occurs in the bedrock of this mountain area, and there can be little doubt that the source of a large part of the placer gold of all these gulches is in the bedrock of the mountain mass from which they have eroded their basins. These placers are rich enough to warrant the assumption that the mineralization of bedrock is considerable. Therefore it seems that this mountain area is a favorable one to prospect, with the object of discovering the gold in definite lodes or zones, although it may be learned that the gold is so dispersed throughout the bedrock as not to form workable lodes, especially in a region like this where the mining costs are high.

In the Chandalar district, on the other hand, probably the most promise lies in its known quartz-lode gold deposits, for the placers so far found there appear to be rather local alluvial concentrations of gold derived from quartz veins near by. A number of these veins have been located and prospected since 1907, but no producing mines have yet been established because of the difficulty in transporting the necessary mill machinery and supplies to the camp. Several of the quartz bodies that have been opened have yielded remarkably good assays. Within 75 feet of the surface much of the gold is free, and in the one or two places where prospecting has been extended to a depth of about 100 feet the free gold content of the sulphide ores is still marked. A more detailed account of this district is given on pages 110–116.

Indications of other minerals besides gold are occasionally found. For instance, pieces of galena are in places associated with the placer gold, and this mineral is reported to occur at several localities in the limestone belt that lies northwest of the gold-bearing schists.

One of these localities is in the upper valley of Wild River and another is on Bettles River. Native copper and silver are reported to have been found in small amounts on a northern tributary of Bettles River in association with placer gold.

On the Middle Fork just above Tramway Bar, in the southern part of the Koyukuk district, there is at least one coal bed of workable thickness. It is about 12 feet thick. The middle 9 or 10 feet is good fuel of a low-grade bituminous quality, but no development of it has been undertaken up to the present time, though it should prove to be serviceable for local use.

HISTORICAL OUTLINE.

Placer gold was first found in this region in the river bars of the Koyukuk some time between 1885 and 1890, when it was visited by a few of the first prospectors who came to the lower Yukon Valley. John Bremner, who was killed by an Indian on Hogatza River in 1888, was one of these pioneers.

Previous to 1898 the placers at Tramway Bar bench, and two other localities several hundred miles down the river, named Hughes and Florence bars, appear to have been the best-known occurrences of placer gold in the Koyukuk Valley, and it is estimated that about $4,000 worth of gold was mined from them. It is interesting to note that Florence Bar is only a few miles below the newly developed Red Mountain placer gold district, situated on the central Koyukuk about 380 miles up the river from the Yukon. Here, in 1910, gold-bearing gravels were found in the basin of Indian Creek, a tributary from the east about 4 miles above Waite Island. A new settlement named Hughes has been established on the east bank of the Koyukuk a short distance above Indian Creek, but it has not been learned whether or not the situation of this settlement has any reference to the former Hughes Bar diggings. The gold of Florence Bar may have been derived from some of the gold-bearing tributaries in this vicinity, such as Indian Creek.

Since 1898 prospectors have searched for gold within the valleys of all the headwater branches of Koyukuk River, with the result that placer gold has been found in greater or less amounts in the gravels of some of the tributaries of John and Wild rivers and the North, Middle, and South forks of the Koyukuk, and also about the source of Big Creek in the Chandalar Valley. Search has also been made for gold in the valleys of Dall and Hodzana rivers, and it is reported that prospects have been found on some of the tributaries of these streams, but so far there has been no production from this part of the region.

DISTRIBUTION AND GEOLOGIC ASSOCIATION OF GOLD.

The search for gold, which has been carried on more or less actively throughout the Koyukuk-Chandalar region since 1899, has been best rewarded on the tributaries of the Middle Fork. Placer gold is now known to occur in many of the creeks and gulches tributary to this river, from Chapman Creek and Tramway Bar on the south to the head of Bettles River, this being roughly the section of the Middle Fork drainage basin which lies within and crosses the northernmost belt of Birch Creek schist in this region, described on pages 35, 38–49. (See Pl. V, in pocket. In fact, with two exceptions, the streams furnishing by far the largest amount of placer gold from the Koyukuk-Chandalar region lie within the drainage area of the Middle Fork of the Koyukuk. The notable exceptions are Mascot Creek, a headwater tributary of North Fork, and South Fork at Gold Bench.

It is only from five to six of these streams that gold may be mined profitably under present conditions, and in many places work has been carried on from year to year with considerable uncertainty as to the result. This uncertainty is due in part to the nature of the gravel deposits but largely to the high cost of all supplies and to the primitive methods of mining, which in turn may be attributed to the general remoteness of the region.

The general features of relief are similar in every way throughout both the Koyukuk and Chandalar districts, and the development of the drainage system that has formed the dominant features of the region and the widespread deposits that have been laid down by the streams of this system are so intimately associated with some of the gold placers that it seems more logical not to separate the descriptions of their relations. The principal characteristics of this association have already been outlined (pp. 58–67). More detailed descriptions of the placer gold-bearing gravels and their geologic association with the widespread gravel deposits of the region will be given for particular localities (pp. 84–110).

It is obvious that the gold-bearing gravels which are buried beneath silts, such as those which partly fill the valleys of Nolan Creek and Hammond River to depths of 50 to 100 feet and more, must have been laid down before the silts were deposited and are therefore older than the silts. If the silts were deposited in these valleys during glacial time the bedrock troughs of the valleys and the gold-bearing gravels along their bottoms must be older than the stage of glaciation during which the silts accumulated. As the period of glaciation of the Endicott Mountains is considered to be contemporaneous, in a general way, with that of the rest of North America—that is, of Pleistocene age—it seems that some of the placer gold-bearing gravels of this region are at least as old as early Pleistocene.

It is possible that before the glaciers were formed some of the valleys of this region contained gold-bearing gravel deposits which were not favorably situated to escape the erosion of the ice and which consequently were removed and had their gold contents scattered throughout parts of the widespread outwash gravels already described. (See pp. 58-66.) This may account for the particles of gold said to be found by prospectors in the terrace gravels at many places. It is probably correct to say that the geologic age of the placer gold ranges from early Pleistocene to the present.

CLASSES OF PLACERS.

CRITERIA FOR CLASSIFICATION.

The methods of working gold-bearing deposits of gravel depend upon their kind and condition. As the kinds and conditions are merely the result of various intergradations of common geologic processes—the wasting away of the hard country rocks by erosion and the transporting, wearing, sorting, and depositing of the loosened materials by water, both in its fluid and frozen state—no sharp distinction can be drawn between the various classes of placer deposits. At the same time they present some differences that may be used to separate them into more or less distinct groups and classes.

The placers in the Koyukuk district may be classed according to the position, thickness, and composition of the various members of the unconsolidated formation in some particular layers of which the gold usually has been more or less concentrated in commercial quantities by the moving water that has washed down or built up the deposits to their present form. These placers may be divided into two groups, one of which occupies the bottoms and the other the side slopes of the present valleys. Each of these groups may in turn be subdivided into two classes, one in which the percentage of barren covering material associated with the gold is small, and another in which it is large.

PRESENT STREAM PLACERS.

The group of deposits that occupy the immediate bottoms of the valleys and that usually lie along the channels of the present streams consists of two classes. The first class comprises shallow gulch, creek, or river placers in which gold is usually found on or near bedrock in a bed of gravel from a few inches to 4 or 5 feet thick. These deposits are generally in unfrozen condition during the summer while the streams are flowing. To mine them it is necessary to move mechanically practically all the overlying unconsolidated mate-

rial and in places also the upper part of the decomposed country rock. The second class comprises gulch, creek, or river placers in which the gold-bearing gravels, as in the first class, lie usually on or near bedrock along the bottoms of the present valleys, but in which they have been deeply buried, in places to a depth of several hundred feet, by gravels, sands, and clays, and locally by a mixture of vegetable matter commonly called muck. The whole overburden is generally quite barren of gold, and on top of it flow the present streams. These deep deposits are generally solidly frozen throughout the year except during the summer in places where streams flow over their surfaces, and except in some of their more porous beds of gravel where underground water is plentiful enough to circulate rapidly. To mine these buried deposits successfully it is necessary to remove the part which contains gold in commercial quantities with the least expense. This is usually accomplished by moving as small a percentage of barren material as possible.

Of the two classes the shallow, periodically unfrozen placers may be considered the younger and more primitive, because this is the position and condition the pieces of gold assume when they are first detached from their bedrock sources by the agencies of disintegration and delivered to the agencies of transportation (chiefly moving water), to be carried and concentrated in the form of placers.

BENCH PLACERS.

The second group of placers comprises the deposits that do not occupy the present stream channels or bottoms of the valleys but are in positions on either or both sides of the valleys, usually at higher levels, where they were deposited when the streams formerly flowed from a few to several hundred feet above and to one or the other side of their present positions. These deposits are generally called bench placers, and they may be subdivided according to position alone into high and low deposits, to express merely their height relative to the present drainage levels. Those that contain gold, however, may be best subdivided into two classes, like those of the first group—that is, according to the position of the gold-bearing layers in the deposit and the relation of these layers to the thickness, composition, and condition of the various materials. One class includes shallow bench placers where a stream does not now flow over the gravels and where the gold is associated with gravels a few feet or less thick, resting either on bedrock or on a layer of more or less compact unconsolidated material that answers the same purpose and is called "false bedrock." Shallow bench placers are mined in a manner similar to shallow gulch or creek placers, by moving practically all the material in the gold-bearing area from the surface

down to the real or "false" bedrock. The other class of this group comprises deep bench placers where the gold-bearing gravels are the same as those of the shallow class but are covered by an overburden of considerable thickness that generally does not contain gold in commercial quantities. These placers can be best mined by methods that do not disturb the surface configuration of the deposit—that is, by means of shafts and drifts or by drifts alone.

UNCONSOLIDATED FORMATIONS.

The condition of the water, whether frozen or liquid, contained in the unconsolidated deposits of this region is important, for it directly governs the method of working best adapted to get any valuable minerals they may contain. Over all northern Alaska the unconsolidated deposits, whether gold-bearing or not, are as a rule firmly bound together by widespread and almost constant frost or ice throughout their thickness and extent. This condition also extends to some depth into the hard country rocks wherever percolating water penetrates them. The amount of unfrozen ground in northern Alaska is a very small percentage of the whole, and even this is usually in an unfrozen condition only for about one-third of the year, during the season of flowing surface water or the few months of summer. Occasionally the larger streams carry enough circulating water through the more porous beds of gravels in their valleys to maintain an unfrozen condition throughout the whole year.

The placers of the Koyukuk district may be classified according to the three elements of position, thickness, and composition, but the fourth element, that of condition, applies so uniformly to nearly all the unconsolidated deposits for the whole or larger part of each year that it is not so distinctive as the other three elements. It is, however, of much more economic importance, because the progress of placer-mining development is largely governed by the frozen or unfrozen condition of the unconsolidated formation.

SUMMARY OF CLASSIFICATION.

The following statement is an attempt to express the above classification more concisely:

Classes of placers in the Koyukuk district.

Group I. Present stream placers. Deposits occupying a position in or under the present flood plains:

Class 1. Uncovered. Shallow gulch, creek, and river placers in which gold is found on or near bedrock associated with gravels from a few inches to 5 or 6 feet thick along the immediate beds of present streams. Largely unfrozen during the summer season of flowing water. Easiest and cheapest to mine.

Class 2. Covered. The same kind of placer as class 1 above, in the same position near bedrock, but buried to depths in places as great as several hundred feet by alluvial deposits that generally do not contain paying quantities of gold. Largely frozen solidly throughout the year except on the surface during summer. More difficult and expensive to mine.

Group II. Old stream placers; bench placers. Deposits occupying positions on either or both sides of and usually at higher levels than the present flood plains.

Class 1. Uncovered. Shallow gulch, creek, and river placers of former drainage channels, where the gold is associated with a few feet of gravel on top of either bedrock or unconsolidated deposits. Often unfrozen. Easiest and cheapest to mine.

Class 2. Covered. The same kind of placer as class 1 above, where the gold-bearing layers may rest on bedrock or a compact layer and are covered to a considerable depth by later deposits that generally do not contain paying quantities of gold. Generally solidly frozen throughout the year. More difficult and expensive to mine.

The foregoing classification of the Koyukuk placers applies equally well to all the stream placers of Alaska, except that frozen ground is not so deep nor so general on the Pacific slope portion, where the climate is not so severe.

A group for residual placers, which in natural sequence should precede group I of stream placers, and a group for beach placers, which should follow group II of stream placers, in all making four groups of placer deposits, would complete the above classification. Residual and beach placers have not been considered here, because in the Koyukuk district they are very scarce.

In the Koyukuk district gold-bearing bench deposits are common and probably more extensive in area than the creek and gulch placers. The benches occupy positions from low banks along the present streams up to heights of several hundred feet on the side slopes of the valleys. So far they have not been mined as extensively as the creek and gulch deposits, because most of them are not in favorable positions with regard to water supply for profitable mining with a small amount of invested capital. They will best be treated by hydraulic methods, and this form of mining has not been developed to any extent in this district.

Thus the Koyukuk placers range from shallow deposits that are unfrozen during the summer to those that are deep and permanently frozen. The arrangement here adopted expresses in a general way the natural progressive sequence of formation from the younger to older kinds, and from the easiest and cheapest to the more difficult and expensive to mine. Though there are all gradations between the most shallow unfrozen to the deepest solidly frozen kinds, with regard to methods of working they may be conveniently separated into two kinds—shallow and deep or surface and underground.

SOURCE OF PLACER GOLD.

It has already been noted that the Birch Creek schist of the Koyukuk district contains a carbonaceous schist or phyllite that has been well silicified. The quartz is rather finely and uniformly disseminated throughout much of the rock, but in some places it occurs largely in the form of gashed and laced stringers of secondary quartz and in more or less lenticular or knotty bodies that have a general tendency to swell and wedge out and follow the curves and crenulations of the schistose structure. In other localities more intense metamorphism appears to have altered the carbonaceous rock with its quartz content into a micaceous quartz schist. That is, this rock apparently varies horizontally from a carbonaceous phyllite, locally having slaty cleavage, to a carbonaceous schist with more or less secondary quartz, at some places finely disseminated, at others more or less segregated; and here and there it has been still further altered into a more typical schist of the micaceous quartz variety, some of which shows graphitic phases.

The form in which the secondary quartz occurs at different localities has undoubtedly been largely influenced by the relative physical rigidity of the various rock members. The more rigid quartzitic phases and igneous rocks have been fractured or shattered into fragments and blocks, affording opportunity for quartz to be deposited in gashed and laced veinlets, while the members of finer-grained texture appear to have been kneaded like putty rather than broken, and as a consequence the quartz now contained in them is more finely and evenly disseminated and is not so conspicuously segregated as in the harder rocks.

The disseminated and segregated quartz content of these rocks may be an original constituent or it may have been introduced by migrating solutions from other rocks during the progress of metamorphic changes, or it may very probably have been derived from both these sources through a long period of metamorphic alteration. Where the rock is fine textured and is a more typical phyllite the quartz is more finely disseminated, and locally, at least, this phase also contains a considerable amount of gold-bearing pyrite distributed through the rock as well-formed, sharp individual crystals. The rock at such localities might be called a pyritized phyllite or schist. A selected sample of fresh sharp crystals of this pyrite from Nolan Creek assays $1.24 in gold to the ton. Where the quartz content of the rock occurs more in the form of knotty segregations and veinlets the pyrite is present in both the country rock and the quartz, though most of the quartz appears to be quite barren; but some weathered pieces of this quartz show oxidized pyrite, cubical cavities from which pyrite has evidently been removed, and small flakes and particles of free gold. Assays of samples from the quartz segregations

and veinlets that occur in the micaceous quartz schist phase of these rocks show that gold occurs sparingly in that phase also.

The evidence outlined above appears to be sufficient to warrant the conclusion that the placer gold of the Koyukuk district has its chief source in the carbonaceous phyllite and micaceous quartz schist phases of the Birch Creek schist, because the pyrite that formation contains is known to be gold bearing and the quartz veinlets and lenses characteristic of parts of it are known to contain free gold. No doubt the form and condition of the gold as it now occurs in the bedrock are the result of one or more cycles of complicated changes and segregations, and the coarser placer gold in the gravels represents gradual accumulations from the erosion of a great amount of this mineralized country rock. Whether the mineralization was confined to any particular rocks, and if so what its distribution within the rocks may be, can not now be definitely stated. Only detailed study will show the real relations and the manner in which they have come about.

In the Koyukuk district proper the evidence goes to show that the placer gold has, for the most part, been derived from stringers and veins in the schists and slates. The definite relation of these to the intrusive rocks is not so evident as it is in the Chandalar district, where the facts in hand go to indicate that the mineralization is genetically related to the intrusion of granites and granodiorites. In this field some fairly well defined quartz veins have been found and considerable prospecting has been done on some of them. These veins occur in association with intrusive rock, a fact which is in accord with the general law governing gold mineralization in other parts of Alaska. This law is, in effect, that the mineralization is closely connected with granitic or dioritic intrusives. Some evidence has been presented elsewhere (p. 33) indicating that the mineralization in the Koyukuk district may not have been confined to the schists but may also have occurred in the younger Mesozoic rocks. It need hardly be added that the evidence at hand is not sufficient to determine definitely that the district may not contain auriferous veins which are genetically related to the intrusive rocks.

THE PLACERS.

KOYUKUK DISTRICT.

DRAINAGE BASINS.

The Koyukuk district may be considered to embrace all the area drained by the North, Middle, and South forks of the Koyukuk, lying approximately between 67° and 68° north latitude and 149° and 150° 50′ west longitude and covering about 4,000 square miles.

The name Middle Fork is here applied to that branch of the Koyukuk which is formed by the confluence of Dietrich and Bettles rivers and flows southward and westward about 75 miles to the point where it is joined by the North Fork, 37 miles below Coldfoot. (See map, Pl. I, in pocket.) The valley of the North Fork is the drainage basin immediately west of and roughly parallel to that of the Middle Fork, and the valley of the South Fork occupies the area east and southeast of the Middle Fork that lies between it and the drainage of the Chandalar basin. These three drainage basins may be considered to constitute the Koyukuk placer gold district, which is noteworthy as one of the most northerly mining communities in the world. Of the three the valley of the Middle Fork is the largest and by far the most important in the region so far as placer mining is concerned. Its gold-bearing creek, gulch, and bench deposits will be described first and considered in upstream order from south to north.

MIDDLE FORK OF KOYUKUK RIVER.

TRAMWAY BAR AND CHAPMAN CREEK.

Tramway Bar is one of the earliest known localities for placer gold in the Koyukuk Valley. Together with two other localities, Hughes and Florence bars, it was known and visited by a few of the first prospectors who came to the lower Yukon Valley between 1885 and 1890, when gold was first discovered in the bars on the Koyukuk. It is situated on the west side of the Middle Fork about 20 miles below Coldfoot. At the locality where it has been worked it consists of a deposit of stream gravels, at least locally gold-bearing, resting on a bench cut in conglomerate and sandstone from 80 to 100 feet above the river. The river has cut a canyon into the conglomerate formation to this depth for 3 or 4 miles, and the coarse unconsolidated gravels, ranging in size from fine gravel to bowlders 1 foot in diameter on top of the canyon walls, appear to be the wash of an old stream which flowed over the bedrock before the downcutting of the canyon took place. This old stream deposit, derived largely from the schistose rocks that form the mountains to the north, extends for several miles westward as a covering of the benches of the Middle Fork valley and far to the eastward on benches in the Chandalar Valley. The present channel of the South Fork of the Koyukuk is intrenched across these deposits in a north-south direction from Hungarian Creek to Granite Creek, and they extend up Mosquito Fork and its northern branch to and over a wide, flat divide, thence down Crooked Creek to its mouth, where they coalesce and appear to be the same as the thick bench gravels that are widely distributed throughout the Chandalar Valley. All the streams above mentioned are more or less intrenched in this gravel deposit, and

scattered over its surface are numerous shallow depressions that hold lakes and ponds. These high wash gravels are not known to contain gold, even in small quantities, throughout their extent or even over any considerable areas. In fact, gold appears to occur in them only at certain localities, of which Tramway Bar, on the Middle Fork, and possibly Gold Bench, on the South Fork, are the best known. The gold at Tramway Bar very likely has been introduced locally from Chapman Creek, an east-side tributary of Middle Fork, at present emptying into it about one-fourth mile above, whose former channel may have flowed across the bench. It is probable that all the bench gold deposits in the Koyukuk district that prove to be of sufficient value to be mined originated in some stream near by. It is said that several trials at mining the Tramway Bar bench deposits were made previous to 1899, and other attempts have been made since that time, the last during the summer of 1908, when four men dug a ditch from several small lakes situated at a higher level about 3 miles back from the river that conveyed ample water to the bench for sluicing. But it appears that none of the different short periods of operation have yielded very satisfactory returns to the workers.

During the winter of 1908–9 prospectors sunk 13 or 14 holes from 9 to 14 feet deep along Chapman Creek from a quarter of a mile to a mile above its mouth. These holes passed through a layer of sand and reddish gravel without gold to a bed of blue schist gravel resting on clay and prospecting from 2 to 3 cents to the pan. Some bench deposits from 20 to 30 feet above the creek about 2 miles above its mouth were also prospected and found to contain from 5 to 10 cents' worth of gold in a layer of blue schist gravel 1 to 3 feet thick, but the deposit was not considered to be favorably situated on account of a lack of an adequate supply of water for sluicing.

Three holes from 12 to 22 feet deep were also sunk in the channel of the Middle Fork through washed gravels to hard conglomerate bedrock, and one of the men who did this work told the writer that these present river gravels showed gold to the amount of 75 cents to the square yard of bedrock surface, and that immediately on the bedrock from 2 to 3 cents to the pan was found. The object of this work was to test the gravels for dredging.

The placer gold at Tramway Bar does not appear to be derived from the conglomerate formation on which it lies.

TWELVEMILE CREEK.

Twelvemile Creek is a west-side tributary to Middle Fork, 12 miles above Tramway Bar and 8 miles below Coldfoot by the river. Its gravels are said to contain a little gold, but it appears to have been worked only casually and without any large reward.

ROSE CREEK.

Rose Creek is a small west-side tributary to Middle Fork about 5 miles below Coldfoot. Discovery claim is 2 miles above its mouth. Here a few surface colors may be found, but the gravels are said to be about 130 feet deep. Claim No. 4 above Discovery, about 3 miles above its mouth, was prospected during the winter of 1906–7 by sinking a hole 113 feet deep to bedrock. Most of the wash passed through consisted of slaty, flat, shingle-shaped gravel, with about 20 feet of blue clay over a thin layer of gravel which rested on bedrock and which contained many colors of gold.

PORCUPINE CREEK.

Porcupine Creek is a west-side tributary to Middle Fork about 3 miles below Coldfoot. Its gravels are said to contain a great many large bowlders. Four men are reported to have worked there in 1901 and to have produced gold enough to average $8 a day to the man.

SLATE AND MYRTLE CREEKS.

Slate Creek is the largest eastern tributary of Middle Fork. The settlement of Coldfoot is situated on its south side at its mouth, approximately 1,450 feet above sea level. About 8 miles above its mouth its principal tributary, Myrtle Creek, enters from mountains on the north, and its main branch heads in the same mountains about 12 miles farther northeast. Its most easterly headwater branch comes from a wide gravel-filled pass about 20 miles east of Coldfoot. This pass is about 2,300 feet above sea level, or 850 feet above Coldfoot. Several depressions in this pass hold small lakes, some of the drainage of which flows westward into Slate Creek and the remainder eastward into a fork of Boulder Creek, a tributary to South Fork.

The thick deposits of washed gravels that occupy the pass between Slate and Boulder creeks extend westward down the broad valley of Slate Creek and join the similar high gravels along Middle Fork valley. The floor of Slate Creek valley averages about a mile in width from the lower slopes of the high mountains on the north to those of the lower mountains on the south. Most of this valley floor is covered by a deposit of washed gravels from 10 to 40 feet thick. The present stream has intrenched itself in these gravels in the upper third of the valley but has not reached bedrock, while along the lower two-thirds of the valley the main stream and the lower 2 miles of Myrtle Creek have cut through the gravels and into the underlying bedrock, so that rock bluffs from 10 to 20 feet high, overlain by gravels from 15 to 30 feet thick, are exposed along their banks. In several places these rock-walled cuts are narrow enough

A. HORSES TOWING FREIGHT SCOW BETWEEN BETTLES AND NOLAN, ON MIDDLE FORK OF KOYUKUK RIVER.

B. MYRTLE CREEK VALLEY.

Looking upstream from bench of claim No. 6. Hydraulic ditch along left slope.

to be called canyons. On the surfaces of the gravel benches, along the valley, are depressions, some of which are occupied by lakes and ponds, that from their position and arrangement appear to represent parts of the courses of one or more old streams that flowed on top of the gravels during a former period.

The bedrock of Slate Creek valley consists principally of a carbonaceous phyllite that shows in places slaty cleavage and a micaceous quartz schist, both of which contain considerable segregated quartz in the form of veinlets, leaflets, and knotty lenses. There are also several dikes of altered dioritic intrusive rock, which has a spekled greenish-gray color and a medium grain. The gravels throughout the valley are the residual débris of these rocks. The dike rock is the hardest and forms the largest bowlders, a few of which are as much as 6 feet in diameter. Most of the gravels are derived from the schistose rocks, and because of this they show a strong tendency to form flat, slabby shingle, the coarser pieces of which average 6 inches in longest dimension. The whole deposit of gravel is very cleanly washed, very little sand, silt, or sediment being mixed with it. As a result water seeps through it readily and it does not pack closely but lies loosely in the bars, which are consequently not easy to walk over.

Placer gold was discovered on Myrtle Creek in March, 1899, by members of a party of gold seekers who came to Alaska during the excitement of 1898. Coarse gold is said to have been first found on claims Nos. 10 and 11, about 2½ miles above its mouth. There is no "Discovery claim" on Myrtle Creek, the claims being numbered from 1 at its mouth to 33 on its headwaters, a distance of more than 7 miles. The gravels along the present stream bed are from 2 to 4 feet in depth and from 100 to 300 feet in width. (See Pl. VIII, *B*.) There are also banks of gravel 6 to 10 feet thick along the sides of the stream in many places, especially on its upper course. In the lower 2½ miles Myrtle Creek has intrenched its channel through the gravel sheet that forms the benches throughout Slate Creek valley and to some extent it has also cut down into the bedrock underneath the bench gravels.

The present stream gravels along Myrtle Creek have been worked more or less from a point near the mouth of the creek up to claim No. 20 but have not proved profitable above claim No. 15. The seven creek claims from No. 9 to No. 15 have been the most productive. Considered in a general way, the gold has been found well scattered across the width of the present bed of the stream and mining has yielded an average of $5 to $15 a day to the man. All the work along the creek has been done with shovel, pick, and sluice box, the loose shingle gravels from 2 to 4 feet thick being favorable for this kind of mining. This work has been carried on more or less actively during each summer since 1899. Nearly all this shallow ground is

now worked out. The largest yield of gold has been mined from claim No. 11; claims No. 12 and No. 9 have been the second and third best producers, respectively. These three claims are on that part of the creek from 2 to 3 miles above its present confluence with Slate Creek, just below the point where it leaves its mountain valley. Below these claims Myrtle Creek flows through the bench gravels of Slate Creek valley, and these together with the underlying bedrock compose its banks. Above claim No. 12 the bedrock slopes of the mountains that bound the real Myrtle Valley come down near the stream on both sides, and here and there it cuts rock bluffs at the bases of these slopes. Thus the richest deposit of gold appears to have been laid down just beyond the mountains, in that part of the creek that was its mouth when the main drainage along Slate Valley may have occupied a more northerly position or when Myrtle Creek was at a higher level and dumped its gold-bearing gravels out upon the gravels of Slate Valley, to be mixed with the bench deposits. The gold of this locality is probably all derived from the wearing down of the bedrock of the mountains from which the valley of Myrtle Creek has been eroded.

The bench gravels along the sides of the lower 2 or 3 miles of Myrtle Creek carry some gold and are now being mined by a small hydraulic plant situated on the east side bench of claim No. 6. These bench gravels consist largely of Slate Creek channel wash. As exposed by the cut of Myrtle Creek along its lower 2 miles they are from 10 to 30 feet thick and rest on a bench of bedrock from 10 to 15 feet above the present stream level. The gold in the gravel benches along lower Myrtle Creek has probably been largely introduced into them by that stream. However, the bench gravels of the Slate Creek valley have been found to contain gold at other localities, especially above Myrtle Creek, and it may be proved that these gravels are more generally gold bearing than the prospecting that has been done up to the present time has disclosed.

The future of mining on Myrtle and Slate creeks apparently depends on the application of hydraulic methods. The only hydraulic plant in the Koyukuk district is now installed on the east side of Myrtle Creek about 1½ miles above its mouth. The dam of this plant is built on the lower end of claim No. 12, and water is conveyed therefrom by a ditch about 1¾ miles long, 3 to 5 feet wide, and 2 to 3 feet deep, dug along the east-side bench to a penstock on the upper part of bench claim No. 6. The fall of this ditch is about 30 feet from the dam to the penstock, or more than 15 feet to the mile. This is a rather steep grade for a ditch of this size, the usual practice in Alaska being to dig such ditches on a grade of 5 to 6 feet to the mile in good ground and about 3 or 4 feet in frozen muck, and smaller ditches with not over 7 feet fall to the

mile. Larger ditches should be built with less grade. Careful work with an ordinary carpenter's level will enable the miner to locate a ditch to a desired grade with not more than 1 foot of error to the mile.

The Myrtle Creek ditch was dug during the summer of 1908, while the pipe, monitors, and lumber for the plant were brought up Koyukuk River to Coldfoot. This material was sledded about 9 miles with two horses from Coldfoot to Myrtle Creek during the winter of 1908–9, and the plant set up during the early part of the summer of 1909. Water was turned on in the middle of July, and some trouble was experienced by the ditch breaking out in places where it was dug through frozen muck. These places had to be flumed with lumber, and after this was done the ditch carried water well, as most of it has good gravel banks. The head of water furnished to the upper monitor from the penstock is about 70 feet. If the ditch were rebuilt with a grade of about 6 feet to the mile from the dam to the penstock, a head of about 90 feet from the penstock to the monitor as it was placed in 1909 would be furnished instead of 70 feet. A pit about 200 feet long, 100 feet wide, and from 15 to 20 feet deep was opened in the bench gravels at this place.

The Myrtle Creek gold is of the size that the miners call shot and wheat gold. It is coarse, clean, and hammered flat to some extent. Some of it is of the size and shape of melon seeds, and nuggets up to the value of $20 are occasionally found. No doubt many of the finer particles of gold are not recovered, as amalgamation plates are not used. The gold rests principally near the bottom of the gravels and in the crevices of the slabby schistose bedrock, which stands on edge and is loosened with picks and shoveled into the sluice boxes after the upper part of the loose gravel has been moved aside.

CLARA GULCH.

Clara Gulch is a short tributary on the east side of Middle Fork that drains the southwest end of the high mountain ridge which separates Myrtle and Marion creeks. It is about 3 miles long, and little more than a mile from Coldfoot. The gravels in this gulch were mined for gold in 1900 and 1901 by half a dozen men, who obtained returns of several thousand dollars.

KELLY GULCH.

Kelly Gulch is a short mountain tributary on the west side of Middle Fork, about 2 miles in a direct line above Coldfoot. About $500 worth of gold was mined from it in the fall of 1901.

MARION CREEK.

Marion is an east-side tributary about 4 miles long that joins Middle Fork about 4 miles in a direct line above Coldfoot. Although it is a large stream and easily accessible, no systematic prospecting has been done upon it, probably because it carries a large quantity of water, and its gravels are not shallow enough to encourage summer work with pick and shovel, and because the district has not advanced far enough in developing winter methods of prospecting with the aid of steam boilers for thawing and sinking in frozen ground to enable the presence or absence of gold in paying quantities to be satisfactorily determined.

Colors of gold are said to occur near the surface of the gravels in this valley. Attempts made during the winter of 1900–1901 to sink holes to bedrock with the aid of wood fires are reported to have been unsuccessful, but in the winter of 1908–9 several men renewed prospecting on this stream about 6 or 7 miles above its mouth, with the aid of a boiler. Bedrock was struck at a depth of about 26 feet, and good prospects are said to have been found. The only result from this work, however, appears to have been the locating of all the placer ground on Marion Creek in the form of 160-acre association claims by a few individuals, who are not real prospectors or miners, but who belong to that speculative class found in all the mining communities of Alaska, who take advantage of the loosely interpreted placer-mining laws of the United States.

EMMA CREEK.

Emma Creek is on the west side of the river directly opposite Marion Creek. Its basin is bounded from south through west to north by a high semicircular divide that rises from 3,000 to 4,500 feet above the Middle Fork in the short distance of 5 to 7 miles, thus giving this basin very steep grades, the average fall being more than 500 feet to the mile, with the result that all the streams within the basin are swift.

At the mouth of its basin the main stream, the confined accumulation of a considerable drainage area, has cut a canyon about 100 feet deep and half a mile long through crystalline limestone and schist into the bottom of an older, wider valley. The Emma Creek valley appears to have been a hanging valley that has been partly dissected, but not enough to obliterate its older configuration altogether.

Some gold has been found in scattered patches of older stream gravels on top of the rock walls of this canyon, but most of the placer gold has been concentrated in the gravels that have choked into the wider funnel-like expansion of the valley at the upper end

of the canyon, the narrow gorge of the canyon, and the upper part of the gravel fan at the lower end of the canyon, where the swift stream has dumped its gravel load into the valley of the Middle Fork. Both the funnel entrance at the upper end of the canyon and the bottom of the canyon are clogged by numerous large bowlders from 3 to 10 feet in diameter. Thus the canyon is a great natural sluice box, with bowlder riffle blocks, through which a tremendous quantity of gold-bearing gravels from the upper Emma Creek basin has been sluiced during a long period of rapid erosion. Without doubt this is the reason why the richest diggings have been found just above the canyon, in it, and just below it. The richest claim has been that at the mouth of the canyon. The upper basin of the creek may be compared to the pit, the canyon to the sluice boxes, and the gravel fan below the canyon to the tailings and dump of an artificial hydraulic mining plant, due allowance being made for the lack of efficiency of the canyon as a sluice with riffles because the pavement of bowlders is not close enough to arrest all the gravel and gold.

The rich placers of Emma Creek were first worked in 1900 and the largest production was attained in that and the two following years. Since then the locality has not been worked so extensively but has produced some gold each summer. The number and large size of the bowlders prevent it from being ideal ground for pick and shovel work. The total production of this stream for the 10 years 1900–1909 is said to be about $160,000.

A few miles above Emma Creek on the west side are two small gulches, Sawyer and Moose, which are reported to contain prospects of gold, but they are full of large bowlders and have not been worked.

WISEMAN CREEK.

Wiseman Creek is a west-side tributary that flows into Middle Fork about 16 miles by the course of the river above Coldfoot. It is a comparatively small stream occupying a large, broad valley bounded by mountains that rise over 2,000 feet above it on both sides. The bottom of this valley is filled over a width of half a mile by deposits of gravel, sand, and silt from 200 to 300 feet thick. These unconsolidated deposits extend more than 6 miles from the mouth of the stream to a point near its head and also for more than 2 miles up Nolan Creek, its principal north-side tributary. The Wiseman basin is the best example in this district of the results of a former drainage system which filled most of the deep secondary valleys with thick deposits of gravels, sands, and clays. The streams that have since occupied most of the valleys that were thus filled have been vigorous enough to carry away a large part of the unconsoli-

dated deposits, but Wiseman Creek is an exception, for it is not large enough to clear its valley of the sediments which fill it, although its elevated position with reference to Middle Fork would be favorable for such a result. In this respect Wiseman Valley is in direct contrast to the basin of Emma Creek, previously described.

Although Wiseman Valley has been located for placer mining throughout its length and width, and even far up on the high, sloping benches along its mountain sides, there has been no mining development of this ground. All the locations were made without any discovery of gold on the land. This was done on the assumption that because gold was known to occur in Nolan Creek, one of its tributaries, it might be expected to be present in the deep deposits of the main valley. Only one prospect shaft has been put down to bedrock in Wiseman Valley. This work was done during the winter of 1908–9, about a mile below the mouth of Nolan Creek. The shaft is 260 feet deep. In going down it passed through 40 feet of vegetable muck, 180 feet of tough blue clay that had to be chopped with an ax, 30 feet of stream-washed gravels, and 10 feet of ground-up black slaty country rock mixed with some gravel. The shaft is dry. Colors of gold are found at the bottom of this shaft and all through the 30 feet of washed gravels, but are not considered to be present in large enough quantity to make the ground at present profitable for drift mining.

During the winter of 1909–10 another attempt was made to reach bedrock on Wiseman Creek. A depth of 335 feet was attained and a pipe driven 30 feet deeper without reaching bedrock.

NOLAN CREEK AND TRIBUTARIES.

General features.—Nolan Creek, a north-side tributary of Wiseman Creek, is about 4 miles long. The bedrock form of its valley is of the mountain-gulch type, and from a point about 2 miles above its mouth to its head it is still narrow and primarily a bedrock valley. In fact this steep-sided V-shaped bedrock valley continues nearly to its mouth, but this would not be apparent if it were not for the information disclosed by mining operations. For 2 miles above its mouth the valley is deeply filled with unconsolidated deposits of glacial silt, the surface of which presents a gradually widening flood plain that slopes gently downstream to join the still wider flood plain of Wiseman Valley. (See Pl. IX, *A* and *B*.)

Nolan Creek and its east-side gulches—Smith, Archibald, and Fay—are the important streams of the district at present, because it is along them that the rich gold-bearing gravels have been found and actively mined. The placers within the Nolan Creek basin are of three classes—bench gravels, shallow gulch gravels, and deeply buried frozen gravels.

A. NOLAN CREEK VALLEY, SHOWING PRINCIPAL MINING PLANTS.

Looking upstream from east side of the valley opposite claim "No. 6 below."

B. NOLAN CREEK VALLEY, SHOWING BOILER HOUSE AND DUMPS.

Looking downstream from upper end of claim "No. 3 below." Mountains forming south slope of Wiseman Valley in background.

Bench gravels.—The character of the bench deposits along Nolan Creek valley suggests that they may be remnants of narrow, crudely washed beaches formed along the mountain sides when the Nolan Valley was an arm of a glacier-dammed lake which occupied the Wiseman Valley. They appear to mark places of rest occupied by the lake at different stages of level. Those that have been found to contain gold in paying quantities are situated from 50 to 200 feet above the present valley floor between Smith and Fay gulches, through a distance of about 1¼ miles. They have been prospected and mined to a moderate extent but are difficult to work to advantage because of an inadequate supply of water for cheaply ground-sluicing away the frozen clay and vegetable muck that cover the washed gravels.

Shallow gulch gravels.—There is not much shallow gold-bearing gravel in the valley of Nolan Creek. What there is appears to be confined to the tributary gulches. The discovery of gold in 1901 in shallow gravels on Fay Gulch a short distance above the point where it joins Nolan Creek first aroused interest in the search for gold within this drainage basin and caused its unconsolidated deposits to be located for placer mining, but actual mining was not actively begun until 1903, when the small amount of shallow ground on Fay, Archibald, and Smith gulches was worked. The lack of boilers and other necessary equipment for steam thawing delayed the investigation of the deep placers for several years. Some work of this kind was attempted with wood fires, however, that resulted in 1903 in the mining of ground from 15 to 25 feet deep on Smith Gulch and on Discovery claim on Nolan Creek at the mouth of Fay Gulch. From 1903 to 1905 Smith Gulch, Discovery claim on Nolan Creek, and claims Nos. 1 and 2 on Fay Gulch yielded considerable gold; but not until 1905–6 were the deeper gravels in the bed of Nolan Valley itself demonstrated to be rich.

Deep frozen gravels.—By far the largest bodies of gold-bearing gravels in Nolan Valley are deeply buried beneath frozen silts and clays. By 1906 several boilers and some steam thawing equipment had been brought to Nolan Creek, and in this year the first successful prospect shaft in the valley was sunk 135 feet to bedrock on the lower end line of claim No. 3 below Discovery. Rich gold-bearing gravels were found at the bottom of this shaft, and since that time placer drift mining in the deep frozen deposits of this valley has been actively conducted by about 100 men.

Up to the present time the most productive ground on Nolan Creek has been found to extend from Discovery to claim "No. 6 below," a distance of about 1¾ miles. The creek extends to claim "No. 8 below," half a mile farther, where it joins Wiseman Creek.

There are also six claims above Discovery, but little gold has been mined above Fay Gulch, which joins Nolan Creek on Discovery claim. The depth of the unconsolidated deposits increases downstream from 20 or 25 feet on Discovery to 180 feet at the mouth of the creek on claim "No. 8 below." This increase is gradual, the depth being from 40 to 70 feet on claims Nos. 1 and 2, 135 feet on No. 3, 155 feet on No. 5, 165 feet on No. 6, 170 feet on No. 7, and 180 feet on No. 8 below Discovery. However, the general configuration of the bedrock is not so regular as these figures indicate, for underground drifting shows that there are considerable irregularities, called "drop offs" by the miners, especially across the bed of the valley. Besides these irregularities of the bedrock surface of Nolan Valley, it carries in many places numerous bowlders, some of them of large size, between which the gold-bearing gravels have lodged. Here and there these bowlders separate the gravels into patches of greater or less extent and, together with the "drop offs," make the work of drifting along the bedrock more uncertain than if the gravels were of uniform size and more evenly distributed, as they are in the Fairbanks district.

Character of gold.—The placer gold from Fay Gulch and the upper part of Smith Gulch, where it appears to be near its bedrock source, and probably has not been carried far, is mostly in the form of rough angular grains. That in Fay Gulch has about as much quartz attached to it as there is gold, the proportion being about half gold and half attached quartz. On Smith Gulch the gold is in more rounded and heavier pieces the farther downstream it lies. Some of the gold in Smith Gulch has a coating of white mineral matter, which the writer has not had opportunity to test, which is said to be lime, but may be some other mineral substance. This coated gold is most common toward the head of the gulch. Either it does not occur on the gold farther downstream or the coating has been worn off of it by travel. The gold from Smith Gulch is of very high grade, its assay value being said to be more than $20 an ounce, which would class it with the highest-grade placer gold known.

The gold in the deep gravels along Nolan Creek is mostly in the form of rounded, smooth, heavy, chunky pieces. Large nuggets are rare; one of the largest, having a value of about $300, was found on claim "No. 1 below," and another, with a value of about $120, was taken from claim "No. 3 below."

MINNIE CREEK.

Minnie Creek is on the east side of Middle Fork opposite Wiseman Creek. Its valley is about 9 miles long and similar in form to that of Marion Creek, which is parallel to it on the south, the two being separated by a rugged mountain ridge about 4 miles broad that rises

over 3,000 feet above the valley floors. The stream is of good volume, and its gravel deposits are similar to those in Marion Creek, containing considerable live water. The presence of this water in the gravels makes it difficult to sink prospect shafts to bedrock. The first hole to bedrock was dug in 1904, and about $500 worth of heavy shot gold was taken from a short drift at the bottom before water drove the prospectors out. More prospecting was done in 1905, but little has been done since. Two men mined about $400 worth in 1906. No doubt this valley will be prospected more thoroughly as the development of the district progresses.

UNION GULCH.

On the west side of Middle Fork, between Wiseman Creek and Hammond Creek, two gulches—Union and Confederate—drain the east side of the mineralized mountain mass that lies between Middle Fork and Nolan Creek. The gravels in both gulches contain gold, but those in Union Gulch, the southern of the two, which is situated about 2 miles above Wiseman Creek, are the richer. Although the deposits on Union Gulch are limited to about one claim in extent, about $30,000 worth of coarse gold has been mined from them. Gold was discovered on Union Gulch in 1901. The largest production was attained in 1902, but work is still being carried on there.

Prospects of coarse gold have been found on Confederate Gulch, but no mining has been conducted there.

HAMMOND CREEK.

Hammond Creek flows into Middle Fork from the northwest about 20 miles, by the course of the main river, above Coldfoot. It is the largest tributary of Middle Fork, being at least 45 miles long and discharging a volume of water equal to about one-fourth of the flow of the main river above the confluence. The Hammond Valley shows strong evidences of having passed through the same stages of drainage development as the smaller tributaries to the south. In modified forms it has bench and deep-gravel deposits and canyon features, somewhat similar to those that have been already outlined for Emma and Wiseman valleys.

Though the Hammond Valley has been prospected more or less throughout its lower 25 miles, gold has been mined only along the lowest part of its course, more particularly in several short gulch valleys tributary to it from the south within 5 miles of its mouth.

Hammond Creek first attracted attention in 1900, when reports of the discovery of coarse nugget gold in the gravels of the river about 2 miles above its mouth, together with verification of the news about Myrtle Creek, caused about 1,000 people to rush to the Koyukuk dis-

trict from Dawson and other settlements on the Yukon. This enthusiasm soon subsided, however, because the diggings did not fulfill expectations.

As on all other streams where gold is discovered in Alaska, the unconsolidated deposits both along the present stream and on the benches of Hammond Valley have been located for placer mining.

Little systematic or continuous mining has been done on the present stream gravels of Hammond Creek, because the large flow of water and the presence of numerous cobbles and small bowlders make pick and shovel labor unprofitable. A wing dam was built on claim "No. 6 above" early in the spring of 1902, at a time of low water, to divert the river so that the gravels in its bed might be mined. Although the summer's work produced about $10,000 worth of gold, the expense of the operation is said to have made the venture unprofitable. Only about $5,000 or $6,000 worth of gold has been mined from this claim since 1902. Spasmodic work from year to year along the banks of the river, chiefly on Discovery claim, has yielded from $8,000 to $10,000. Most of the gold has been of the coarse nugget variety, some pieces being of large size. One nugget having a value of $849 was found on claim "No. 6 above," another worth $842 was found on Discovery claim, and one worth $1,000 and another worth about $1,100 have been mined in this valley.

On Discovery bench claim, which is on the south side of Hammond Creek about 1½ miles above its mouth, several attempts to discover deep gold-bearing gravels in the frozen deposits were made without success. During 1909 two new shafts were sunk to bedrock on this claim. The first shaft is located about 350 feet south of the present channel of the river, which at this place is running against bedrock on the north side of the valley. At a depth of 66 feet this shaft reached bedrock, the surface of which was found to be sloping toward the north. A second shaft was sunk about 200 feet north of the first, where the bedrock surface is also about 66 feet down. Here the bedrock was found to be sloping to the south, toward the first shaft. In drifting southward along this bedrock surface it was found to have a grade of about 4 feet in a distance of 20 feet along the slope. From this it is concluded that an old channel of the river is situated between these two shafts. A drift on bedrock southward across the supposed old channel to the first shaft is reported to show the presence of gold in paying quantities, and during 1911–12 profitable mining has been conducted upon the deep channel gravels along this stream between Vermont Creek and its mouth.

GOLDBOTTOM, SWIFT, AND BUCKEYE GULCHES.

Along the south side of Hammond Creek, between the Middle Fork and Vermont Creek, are several gulches that drain the north face of

the mineralized mountain mass which has been already referred to in describing the placers of Nolan Valley and Union Gulch and will be mentioned later in the discussion of Vermont Creek. The profitable ground on these gulches is near their mouths, where they have accumulated considerable washed waste from the mountain slopes to the south, more or less mixed with bench-gravel remnants of river deposits along the south side of Hammond Creek. The principal gulches are Goldbottom, Swift, and Buckeye.

Goldbottom Gulch heads against Union and Confederate gulches. About half a claim length, 600 to 700 feet of ground, at its mouth has proved fairly profitable to mine and has yielded between $5,000 and $6,000. In 1904 a $400 nugget was found here.

Swift Gulch is a little larger than the others. It heads opposite Smith and Fay gulches. Work on it at various times has yielded the equivalent of wages and occasionally a small amount of coarse gold. Some of the gold in this gulch is coated with white mineral matter like that on Smith Gulch.

Buckeye Gulch is a small tributary a short distance below Vermont Creek. Gold equal to the daily wage scale of the district—that is, from $6 to $10 a day to the man—has been occasionally mined from the claim at its mouth.

VERMONT CREEK.

Vermont Creek is a small stream flowing into Hammond Creek from the south about 5 miles from the Middle Fork. It is formed by two branches, an east or left one, about 2 miles long, and a west or right one, about 3 miles long, which flow through deep gulch valleys that join about a mile from Hammond Creek. These gulch valleys head against similar gulches that are tributary to upper Nolan Creek and drain southward. By way of the east fork of Vermont Creek there is a pass through the mountains to a short gulch near the head of Nolan Creek. This pass is about 800 feet above Hammond Creek, or 2,900 feet above sea level. Some small spruce grows in this pass but becomes sparse on its bounding slopes.

The bedrock in Vermont Creek is the same as that already described as occurring in Nolan Valley. This carbonaceous phyllite formation extends northward through the mountains from Nolan Creek to Hammond Creek and is well exposed on the east or left fork of Vermont Creek and to the east of it for some distance. It also outcrops along the south banks of Hammond Creek for some distance downstream from the mouth of Vermont Creek, where much of it shows slaty cleavage. On the upper part of the east fork of Vermont Creek, where unweathered exposures may be observed, it is found to be mineralized with pyrite in the same manner as on Nolan Creek, and it is here that quartz veinlets along joint cracks may be easily seen.

One of the veinlets about 1 inch thick was observed to be mineralized by sulphides and free gold in flakes and specks. No doubt there are other veinlets so mineralized.

Placer gold was discovered on Vermont Creek August 25, 1901, and has been profitably mined there ever since. Discovery claim is located on the main lower part of the creek just below the forks. Two claims, covering about half a mile, on the east fork have been good shallow mining ground, and Discovery claim and the two claims below Discovery contain good values. Thus the rich gravels extend over five claims for a distance of about 1¼ miles, of which three-fourths of a mile is below the forks and one-half a mile along the east fork. On the west fork of Vermont Creek gold has not been found in paying quantities. Claims "Nos. 1 and 2 above," about half of Discovery claim, and claim "No. 1 below" have been worked out. The gravels on the east fork average about 3 feet in depth and are not very wide, as the bottom of this gulch is narrow. On Discovery claim the valley bottom broadens and the gravels are from 200 to 300 feet wide. On claim "No. 1 below" their width increases to about 400 feet. The gravels become somewhat deeper on the lower end of claim No. 1 below Discovery and decidedly deeper on claim No. 2 below Discovery. In fact the lower half mile of Vermont Creek is flowing over deposits that may be more properly considered, at least in large part, to be bench deposits of Hammond Valley, for these deposits are not shallow gravels, largely unfrozen, lying on the bedrock floor of a narrow rock-cut gulch such as extends above claim No. 2 below Discovery, but are deep frozen accumulations of gravel, sand, and clay that are directly related to similar extensive bench deposits which occur along the sides of Hammond Valley. Although the largest part of the unconsolidated stream deposits on this claim belongs to the sediments of Hammond Valley, there appears to be little doubt that most of the gold in this deep ground has been derived from Vermont Creek.

About the center of claim No. 2 below Discovery, on Vermont Creek, a sinking and drifting operation in these deep frozen deposits has proved very successful. This work was begun during the winter of 1908–9. The shaft is about 90 feet deep. At a depth of about 50 feet it encountered a bed of cemented sediment 11 feet thick which is termed a "false bedrock." Below this hard bed is from 18 to 20 feet of clay, succeeded by 7 to 8 feet of washed gravel. In August, 1909, a drift about 200 feet long had been driven in a direction up Vermont Creek and another drift about 100 feet long across the direction of Vermont Creek.

The Vermont Creek gold is mostly coarse and rounded. Several nuggets worth more than $200 have been found.

STREAMS BETWEEN HAMMOND CREEK AND GOLD CREEK.

Above Hammond Creek gold has not been found in paying quantities on any of the west-side tributaries of Middle Fork, nor is it known to occur on Dietrich River, the northernmost headwater branch of the Middle Fork, whose valley for the most part is cut in the limestone formation of the Bettles group, which lies northwest of the gold-bearing formations of the Koyukuk district.

From Hammond Creek to Gold Creek, a distance of 7 or 8 miles, the Middle Fork follows a course from northeast to southwest. Between the valley of Minnie Creek and this section of the Middle Fork valley there is a high mountain ridge similar to the ridge between Minnie and Marion creeks. All the southern slope of this mountain mass is drained by tributaries of Minnie Creek, while its northern slope is drained by a number of short, steep gulch streams that flow into the Middle Fork, and by Gold Creek, which flows around its northern flank. The principal short gulches between Minnie and Gold creeks that drain this mountain ridge, named from south to north, are Bluff, Rainbow, Montana, Coon, Nugget, and Sheep. They have been prospected more or less, and a little gold has been mined from the most northerly one, Sheep Gulch, on which, it is reported, two or three claims show good prospects and one small area yielded about $800 worth of gold to the box length during the summer of 1908. By "box length" is meant an area about 12 feet long by 16 feet wide, or a bedrock surface of approximately 200 square feet.

GOLD CREEK.

The present form of the valley of Gold Creek apparently shows that it has passed through a series of drainage changes somewhat similar, but of modified form, to those that have taken place in the development of the basin of Emma Creek, but as it is impossible to describe these changes clearly without illustrating its features by a detailed topographic map, only an outline will be given here.

The most marked feature that this valley now presents is a canyon section 1½ miles long in its lower part, which is cut at right angles across a sloping bench of bedrock on the east side of the valley of Middle Fork. One mile above the mouth of Gold Creek this narrow canyon is 50 feet deep and its depth increases upstream for about half a mile, reaching 200 to 250 feet. In its upper part, where deepest, it appears to have cut down through a spur that slopes from the mountain mass which lies on the south between Gold Creek and Sheep Gulch. On the north wall of the canyon, in line with this mountain spur, there is a small but prominent bedrock knoll that appears to be a remnant of the mountain spur on the south side of

the canyon. Just above or northeast of this knoll, in the bedrock of the north wall, there is a depression about 50 feet deep and 300 feet wide, the bottom of which is about 200 feet above the present bottom of the canyon. This depression is filled with stream-washed channel gravels which in their present position are resting on top of the canyon wall. These washed gravels appear to occupy a part of a former channel of Gold Creek when it flowed at a level 200 feet higher than it does now. The significance and probable course of this old high channel will be discussed later in connection with the gold placers that occur on Linda Creek, with which it appears to be closely related.

The fall of Gold Creek from the head of its canyon to its mouth is about 200 feet in a distance of less than 2 miles. Above this canyon the valley widens out somewhat and has a deep V-shaped cross section whose slopes rise steeply to a height of about 1,000 feet above the creek. At this elevation, which is about 3,000 feet above sea level, the steep lower slopes form a shoulder, with more gently inclined slopes on the higher parts of the mountains (see Pl. VII, *B*, p. 58)—that is, the present valley of Gold Creek shows strong evidence of having been rather abruptly cut down into an older land surface which had a moderately rolling mountain relief that was much less rugged than the topographic form of this region to-day.

This deep V-shaped portion of the valley extends upstream from the head of the canyon for about 3 miles, and in this distance the fall of the creek is about 400 feet. About midway of this stretch and also at the upper end of it there are two more contractions in the valley, where the creek runs through short, low-walled, narrow gorges or small canyons. The halfway gorge appears to be caused by the presence of a hard dike of intrusive diorite which outcrops on the north slope of the valley and whose greater resistance to erosion over that of the softer schists on both sides of it has offered a barrier to the down cutting of the stream. The uppermost gorge, about a mile farther upstream, is cut through a low ridge of schists that are harder than the surrounding schists. This barrier rises about 60 feet above the present creek bed. Thus the lower half (4 or 5 miles) of Gold Creek valley has three contracted features, the first and deepest of which is a canyon, the second and third gorges. Between these three contracted features there are two wider V-shaped portions of the valley and it is in these portions that the richest gold-bearing gravels have been found and mined.

Above the upper gorge the upper half of the Gold Creek valley is wider and has a form entirely different from that of its lower half; there are no canyon-like contractions, and instead of a sharp deep V-shaped cross section it has more open and gradually sloping sides. This form continues through 3 or 4 miles to its headwater gulches.

The country rocks of the Gold Creek valley are practically all schists. The outcrops in the lower half of the creek are mostly of the carbonaceous phyllite schist that occurs in the basins of Wiseman Creek and Hammond Creek, already described; in the upper half of the valley the bedrock is mostly of the micaceous quartz schist variety that occurs to the south, in the Myrtle Creek basin.

The diorite dike that forms the gorge about 1½ miles above the canyon is the only intrusive rock seen in place. Large hard bowlders of this dike rock are common in the creek wash, from the dike down to the head of the canyon, and as bowlders of this rock were not observed above the dike it seems that they are mostly if not all derived from this dike and that this dike is the principal occurrence of igneous rock in the valley. On the mountain ridge that bounds upper Gold Creek valley on the northwest there is a considerable mass of limestone of the Bettles group that forms the top of a mountain 3,900 feet high, and from the presence of a considerable number of cobbles and small bowlders of crystalline limestone in the creek wash it may be concluded that considerable of this limestone formation, which overlies the schists and was probably at one time much more extensive in distribution, has been eroded away.

The probable bedrock source of the gold in this valley is not so evident as it is in those of Nolan and Vermont creeks, but there are indications of a pyrite mineralization of the phyllite schist bedrock in the vicinity of the diorite dike on lower Gold Creek. Whether this dike has had anything to do with the primary introduction of gold-bearing minerals at this place is not known. As the influence of igneous intrusives is so common a phenomenon in other parts of Alaska it is fair to presume that it may have been exerted here.

Placer gold was discovered on Gold Creek in 1900 and has been mined more or less throughout 6 miles of its length from claim No. 4 below Discovery, at the head of the canyon, to claim "No. 19 above," on its headwaters. The most profitable diggings have been the shallow stream gravels that occur in the two sections of the valley situated between the canyon and the middle gorge and between the middle and upper gorges. The claims located between the head of the canyon and the middle gorge are designated Discovery, Nos. 1 to 4 below Discovery, and Nos. 1 and 2 above Discovery. Between the middle and upper gorges the claims are Nos. 3 to 6 above Discovery.

No mining of consequence has been done below claim "No. 5 below," in the head of the canyon. In 1903 this claim is said to have yielded gold equal to $12 a day to the man, or the daily wage at that time.

Claims "Nos. 3 and 4 below" are reported to have yielded during 1901–2 over 100 ounces of gold, or about $2,000 worth, and this

ground has been worked since then somewhat regularly, with about the same yearly production. Most of this mining has been done in the winter by thawing with wood fires and drifting into a low bench of frozen gravel and earth on the north bank of the creek.

Discovery claim is reported to have yielded in 1900 about $85 a day to the man, and work on this claim was continued until 1904, when the good-paying ground was about exhausted. The gravels of this claim were shallow and easily worked, especially toward its upper end, where they were richest. About $15,000 is reported as the production for 1901 and about $85,000 is stated to be the total production of this claim.

In 1901, besides Discovery, claims "Nos. 1, 3, 4, and 5 above" were actively mined. "No. 1 above" is said to have paid a little better than wages and to have produced a net profit of about $4,000 while it was mined. "No. 2 above," the upper part of which is in the halfway gorge, did not prove very good and yielded only from $4 to $8 a day to the man. Claims "Nos. 3 and 4 above" and the lower two-thirds of "No. 5 above," which are situated between the two gorges, were very good producers. The creek gravels were shallow and easy to handle. No definite figures of the amount of gold mined are available, but it is reported to have been as much as that of the claims located between the halfway gorge and the canyon.

Claims "Nos. 6 and 7 above" have produced very little. No. 8, which is above the upper gorge, is reported to have produced $500 to the box length for a short distance. Two men mined a few hundred dollars' worth of gold from it in 1909. Only a very little prospecting and assessment work has been done on claims "Nos. 9 to 17 above."

In 1909 four men were mining with picks, shovels, and sluice boxes on claim "No. 18 above" and were producing about $10 a day to the man. "No. 19 above" is said to have produced $500 to the box length in 1904. Two men were working on this claim in 1909, but the returns were not very profitable.

Most of the placer-gold deposits on Gold Creek are shallow stream gravels without any large amount of overburden. For this reason it has been one of the best valleys for pick and shovel mining in the district. Some of the gold on claim "No. 19 above" and in the gulches near by consists of rough, light pieces that appear not to have been transported far from their bedrock source, but most of the gold has the form of rounded shotlike pieces and small, smooth nuggets.

LINDA CREEK.

Linda Creek is a small stream about 4 miles long that drains the southern half of a gravel-filled depression on the east side of the Middle Fork about a mile north of Gold Creek. The part of this wide depression occupied by Linda Creek is the southwesterly arm

of a semicircular bend east of a mountain 3,000 feet high, which stands isolated from the main mountain ridges that bound the valley of Middle Fork. Linda Creek heads in the elbow of this bend in a large pond which, with several other smaller ponds, occupies a flat gravel and silt covered watershed between Linda Creek and another small creek of about the same length that drains the northwesterly arm of the depression and flows into Middle Fork about 6 miles above the mouth of Linda Creek. Over the broad bottom of this depression throughout its extent is spread a covering of waterworn gravels and silts, over which flow the creeks that drain its arms, but at about the middle of their courses these creeks have washed through the unconsolidated deposits and cut shallow channels into the underlying bedrock. Linda Creek, however, has done practically no bedrock cutting and does not occupy a valley of its own making, and it appears evident that any placer gold now occurring in the gravels of its channel must have been introduced there by some agency other than the present stream.

The most probable source for the placer gold that has been found on Linda Creek is Gold Creek. In the description of lower Gold Creek the stream-washed deposit of gravel about 200 feet above that stream on the north wall of its canyon was referred to as having a possible intimate connection with the placer gold that has been found on Linda Creek. The gravels on top of the canyon wall occupy a depression in the bedrock about 300 feet wide and 50 feet deep, and the exposure has every appearance of being a cross section of an old high channel of Gold Creek before that stream was diverted down its present canyon. If the rock knoll that forms the west side of this depression in the north wall of the canyon is, as it appears to be, a remnant of a former continuation of the mountain spur opposite it, on the south wall of the canyon, then the most natural course for Gold Creek to have followed when at this higher level would have been to the north toward Linda Creek, across the sloping bench that now intervenes. The direct distance across this bench between the high gravels in Gold Creek canyon and the locality where placer gold occurs on Linda Creek is a little more than a mile and the fall of the surface is about 300 feet. The indications that a stream flowed between these two points are not particularly marked. There is no strong surface evidence of a former channel unless a slight depression or sag of the surface, from 300 to 600 feet wide, indicated by a timberless strip overgrown with moss and dwarf willows, is considered to mark a frozen channel that is too cold to foster a good stand of timber such as now grows along both sides of it. This barren strip of land seems to connect the high gravels on the canyon wall with the placer-gold locality on Linda Creek, but whether it is the course of an old channel can be proved only by prospecting, and even if

this is proved it may not be found to contain gold, especially throughout its length.

Gold is said to have been first found on Linda Creek in 1901. The only ground that has been mined is on Discovery claim, situated about half a mile above its mouth, and only the lower half of this ground has proved very productive, $18,000 worth being mined from it in 1902. The gold is similar to that of Gold Creek.

BETTLES RIVER AND TRIBUTARIES.

Bettles River is the large eastern headwater branch of the Middle Fork of the Koyukuk. Its basin extends over 30 miles from east to west and 25 miles from north to south, in a region of rugged mountains between the Middle Fork and upper Chandalar River. Its longest and largest tributaries flow from the north out of mountains composed largely of the crystalline limestone that overlies the gold-bearing schist formations. Its southern tributaries are shorter and flow almost wholly over the same schist formations that extend to the south from Gold Creek to Slate Creek. This valley was not visited by the writer. The information given here is taken from the report by Schrader and notes gathered from prospectors who have worked on the creeks in this basin at various times from 1900 to 1909.

In 1899 a United States Geological Survey expedition in charge of F. C. Schrader traveled through this valley, mapped it, and noted its principal geologic features. Schrader describes a more or less mineralized belt associated with a dioritic intrusive mass on Horace Mountain, on the west side of Robert Creek opposite Sheep Creek, but no valuable mineral deposits or rich gold placers have been found there so far. Prospects of gold are found, however, and small amounts have been mined on some of the tributary streams that have eroded into the underlying schist formation.

Emory Creek is a short south-side tributary of Bettles River that joins it about 8 miles above its mouth. It is about 3 miles long and heads north of and opposite claim No. 8 on Gold Creek. It is said that a total of about $10,000 worth of gold has been mined from the gravels of this creek. The gold occurs on bedrock among bowlders which must be rolled aside to get the gold. Most of the mining was done several years ago. Only one man was working there during 1909.

Garnet Creek is a south-side tributary about 5 miles long, 18 miles above Middle Fork. It is reported to have yielded $7 to $9 a day to the man several years ago.

Mule Creek is a small north-side tributary opposite Garnet Creek. It heads in the limestone formation but has cut down into the underlying schists on its lower course. On a low bench about 2½ miles above its mouth good prospects have been found at a depth of 8 feet

and $80 was produced here in 60 hours' work. About 1¼ miles above its mouth gravels 2 feet deep yielded a dollar an hour to the man. Small nuggets of native silver and nuggets of copper as large as 7 pounds have been found on this stream.

Prospects of placer gold have been found on a number of other creeks about the headwaters of Bettles River, namely, on Eightmile, Phoebe, Spruce, and Sheep creeks, and especially on those tributary to Robert Creek, which is the principal headwater branch of Bettles River. The gold is found on the lower parts of the tributaries to Robert Creek, where they cut down into the schist beneath the massive limestones.

Except on Emory Creek only prospect work has been done on all the streams tributary to Bettles River that have been mentioned.

SOUTH FORK OF KOYUKUK RIVER.

GENERAL FEATURES.

The South Fork of the Koyukuk is one of the largest and longest branches of that river. It rises about 10 miles west of Chandalar Lake, just south of the headwaters of Bettles River, and flows southwestward for about 175 miles. Its general course is parallel to that of the Middle Fork throughout its length. At no place are the main channels of these two rivers more than 25 miles apart, and at one place a few miles below Tramway Bar their main channels approach within 7 miles of each other.

The three large tributaries to the South Fork, Fish Creek, Jim River, and Mosquito Fork, all flow from the east, where they have their sources in mountains from 4,000 to 5,000 feet above sea level. These mountains are made up of the schistose formations that compose the wide belt of metamorphic rocks between Dall and Jim rivers. These three streams head against the headwaters of Dall and Hodzana rivers, and of West Fork and Crooked Creek, west-side tributaries of the Chandalar. Some prospecting for placer gold has been carried on within the valleys of these streams at different times during the last 10 years, but though prospects are reported to be widely distributed no mining has been undertaken.

In 1909 the Geological Survey party panned the gravels on the upper part of the south branch of Jim River and found colors of gold. The stream on which these colors of gold were found has been named Prospect Creek. (See Pl. I, in pocket.)

GOLD BENCH AND VICINITY.

The best-known placer-gold locality in the valley of the South Fork is named Gold Bench. Here there is a deposit of high-stream gravels situated on the northwest side of South Fork about 10 miles south of the Tramway Bar bench on Middle Fork, and apparently belong-

ing to the same class of deposits. It is usually reached by a trail about 8 miles long that leaves the Middle Fork near the halfway road house, 28 miles below Coldfoot, or 32 miles above Bettles.

The gold-bearing gravels lie on top of a sloping bench of thick unconsolidated wash deposits in a semicircular bend of the river. On the south side across the river these unconsolidated deposits rise to a height of 200 to 300 feet above the river. The surface deposits, in which most of the gold has been found, are mostly of fine washed stream gravels, composed largely of schist pebbles, a considerable amount of quartz pebbles, some of flint, and a few bowlders and cobbles of igneous rocks. The best gold-bearing gravels mined were from 18 to 24 inches thick, distributed over an area about three placer claims (60 acres) in extent. Most of the gold rested on a "false bedrock" of reddish sand from 2 to 12 inches thick, and the richest yield was obtained from an area 150 to 200 feet wide and about a quarter of a mile long. Some of this shallow ground was so rich and so easily handled that from $80 to $90 a day to the man was mined with rockers, and in 1900–1901 an extensive shovel and sluice-box operation is reported to have yielded $85,000 worth of gold. The total production for Gold Bench is estimated to be about $150,000.

In a few places deeper layers of the reddish sand with which paying quantities of gold were associated were found from 6 to 8 feet beneath the surface. Shafts sunk into the bench deposits to a depth of 20 feet have failed to reach solid country rock, but some colors of gold are found scattered through the washed deposits, which are all crudely stratified and range from coarse to fine material, the finer fragments being mostly of flat bluish-gray schist.

The gold is in the form of fine, flaky, light, and very much flattened pieces, the largest of which had a value of $3.50.

The bedrock source of the gold is not known. It may have been washed from the direction of Tramway Bar bench, as a low valley-like depression filled with channel-washed gravels extends from that direction, but it appears more probable that the gold may have come from the mountains that border the south side of the river opposite and for some distance above Gold Bench. These mountains are apparently formed of igneous rocks, largely diabases, which may have intruded the schist formations with which they are associated, and it may be that these igneous rocks have an intimate relation with the origin of the placer gold. On the south branch of Jim River, where colors of gold were found on Prospect Creek, the mountains that form the north side of the valley appear to be made up largely of the same igneous rocks.

One of the best reasons for believing that the Gold Bench gold may be derived from the mountains that lie between the South Fork

and Jim River is that placer gold is known to occur on some of the streams that drain from this group of mountains and also in other bench-gravel deposits on the South Fork above Gold Bench. Three of these bench deposits are named Ironside and Grubstake bars and Eagle Cliff.

Ironside Bar is a gold-bearing bench deposit about a mile above Gold Bench on the south side of the river channel, where prospects of gold have been found and a little mining has been done. Grubstake Bar is a similar deposit on the northwest bank of South Fork about 9 miles above Gold Bench. The bench is low and was worked with sluice boxes in 1900–1901 by two men who obtained about $2,000 worth of gold. Eagle Cliff is likewise on the northwest bank of South Fork about 2 miles above Grubstake Bar. It is a deposit of well-washed gravels resting on top of a rock-cut bench from 10 to 12 feet above the low-water stage of the river. In 1899 it was mined with a waterwheel to raise water from the river for washing the gravels. The gold found here is coarse, rounded, and about the size of wheat grains. During 1910 about $1,500 worth of gold was mined from these benches by four or five men.

DAVIS AND OTHER CREEKS.

Davis Creek is a stream about 5 miles long, flowing from the mountains about 4,000 feet high that lie to the southeast between South Fork and Jim River. It joins South Fork about 8 miles above Gold Bench and is one of the first known placer-gold streams in this valley. The bars at its mouth are usually dry, as the stream apparently sinks into unfrozen gravels, but there is a good flow of water above its mouth, where it has cut into thick deposits of washed gravel. A small amount of gold occurs in these gravels and they have been mined to a small extent at intervals for the last 10 years. It is reported that above Davis Creek there are prospects, but no good paying quantities of gold in several creeks flowing from the same mountains, and also on Wilson Creek, a north-side tributary to South Fork about 21 miles above Gold Bench. It is also reported that loosely scattered colors of gold may be found in the gravels along South Fork as far up as Boulder Creek, which rises opposite the upper basin of Slate Creek; but no mining has been done along this part of the river.

HEADWATERS OF GLACIER CREEK.

Glacier Creek, a large north-side tributary of the upper South Fork, about 10 miles long, heads against Gold Creek and two south-side tributaries of Bettles River. Its main valley is so deeply filled with unconsolidated deposits that it has not been prospected. Gold was discovered in 1901 on its principal headwater branch,

California Creek, and two of its tributaries, Jim and Boer gulches. Shovel and sluice-box mining operations have been carried on in a small way by several men each summer since 1901, but this work has never yielded much more than the equivalent of the current wages of the district and hence has not proved very attractive. Two men who were working on Jim Gulch during the summer of 1909 planned to carry on prospect work in some of its deeper frozen gravel deposits during the winter of 1909–10.

NORTH FORK OF KOYUKUK RIVER.

GENERAL FEATURES.

The North Fork of the Koyukuk is a large stream that rises on the south side of the Arctic divide west of the head of Hammond Creek and drains a north-south valley over 60 miles long and from 10 to 15 miles wide that lies west of and parallel to the Middle Fork Valley. The upper part of the North Fork Valley is in mountains of the same limestone formation that occupies a wide belt north of Bettles River, extends westward across Dietrich River, and crosses Hammond Valley about 25 miles above its mouth. The southern half of the North Fork Valley is in the schist formations that underlie the massive limestones to the north. About halfway up the valley, some 35 miles above its mouth, are several small creeks that carry shallow gold-bearing gravels. The first discovery of gold in this valley was made on Washington Creek in August, 1902; in September of the same year gold was found on Mascot Creek, a short distance farther west. Supplies may be taken to this locality by way of the North Fork in poling boats, but the usual practice has been to use a winter sled route from the Middle Fork by way of Wiseman Creek, at the head of which there is an open pass about 800 feet above the main rivers. The distance from Nolan Creek on Wiseman Creek to Mascot Creek is about 10 miles.

Washington Creek, which heads against several of the lower west-side tributaries of Hammond Creek, has not so far yielded enough gold to encourage serious mining operations, although some coarse smooth gold is found in its gravels.

MASCOT CREEK.

Mascot Creek is the only stream in the North Fork basin that has been extensively mined. Its bedrock is a micaceous quartz schist and its gravels are shallow, being nowhere more than 3 feet and in some places but a few inches deep. While the gravels were not considered to be very rich by the miners, the ease with which they could be handled made the work very profitable, it being little more than equivalent to what is termed "cleaning bedrock" in an ordinary

hydraulic operation. The gold rested mostly upon bedrock or in the lowest layers of gravel, and to some extent in the soft, decayed bedrock, which in places was removed to a depth of a foot. The gold mined was coarse—large nuggets, some worth $100, being found. The ease with which these deposits could be handled made it possible to carry on the mining with a profit of about 70 per cent of the yield, and when the extremely high costs of that time are considered the operations on Mascot Creek may be said to be the most profitable that have ever been performed in the Koyukuk district.

Mascot Creek is a short stream. The ground that has been mined extends over 11 claims, or less than 3 miles in length, from claim No. 3 below to claim No. 7 above Discovery. Discovery claim was the best. It yielded about $13,000 in 1903, or a total of $25,000 for that year and the two following. Claims Nos. 1 and 2 below Discovery are said to have produced a total of about $20,000 each, and claims Nos. 1 and 2 above Discovery the same amount each. Claim "No. 3 above" yielded about $25,000 in 1903 and a little in 1904. "Nos. 4 to 7 above" produced the equivalent of wages. The gross yield of Mascot Creek up to 1909 was about $150,000, of which $90,000 worth was mined in the summer of 1903 and the remainder during the two following summers.

In 1910 mining was revived on Mascot Creek in a small way, on bench gravels situated along the right side of the valley about 60 feet above the stream, opposite claims "Nos. 1 and 2 below." About $2,000 worth of gold was mined.

WILD RIVER.

Wild River enters the Koyukuk from the north about 13 miles below the mouth of North Fork. Its valley lies between that of North Fork on the east and John River on the west, but it is not so long or large as either of these streams. It is probably not over 50 miles long in a direct north-south direction, but the main stream is longer than this, because the lower half of its course is very winding. The upper part of the valley crosses the gold-bearing schist belt from 30 to 40 miles north of Koyukuk River, and small amounts of gold have been mined from three creeks lying in this schist belt. The first one of these creeks in upstream order is Birch Creek, an east-side tributary, from which about $10,000 worth of gold was mined during 1905–6.

About 10 miles above Birch Creek the river flows from a lake, and on two small creeks that flow into this lake from the east some gold has been mined. The southern of these streams is named Lake Creek. In 1903–4 gold to the amount of $2,000 was taken from a claim on one of its headwater gulches. The gold was coarse, some of the nuggets ranging in value from $90 to $150.

Spring Creek is the next stream above on the same side of the lake. The claim that has been mined is located about 1 mile from the lake. It yielded about $5,000 in 1907, but the summer of 1908 was so dry that there was not enough water available for advantageous work.

JOHN RIVER.

John River is one of the largest northern tributaries of the Koyukuk, which it joins about 2 miles above Bettles. It is about 120 miles long and crosses the Endicott Mountains in a deep valley that has its head in a pass across the Arctic divide at an elevation of about 2,500 feet above sea level.

From 40 to 60 miles above its mouth this river crosses the southwesterly extension of the Koyukuk belt of gold-bearing schist. North of this belt is the same massive limestone formation that overlies the schists on North Fork, Hammond Creek, and Dietrich and Bettles rivers to the northeast. Schrader has noted a zone of sulphide mineralization in this belt of schistose rock, and the localities where prospects of gold have been found and small amounts mined are in this belt. No gold-bearing deposits have been found north of this schist belt.

Crevice Creek, which lies in these rocks on the east side of the river, and Fool Creek and its tributaries, on the west side, are the only streams on which encouraging prospects have been found up to this time. About $1,800 worth of gold was mined on Crevice Creek in 1904 and good prospects were found on Midas Creek, a tributary of Fool Creek, in 1905, but these discoveries have not led to further development.

DALL AND HODZANA RIVER REGION.

Considerable search has been made for placer gold in the valleys of Dall and Hodzana rivers and their tributaries. It is reported that some prospects have been found in this district, but so far as known no mining has been done on a commercial basis. Much of this field has not been examined, but the evidence in hand goes to show that the geologic conditions are not unfavorable to the occurrence of gold placers, and that further prospecting would seem to be justified.

CHANDALAR DISTRICT.

GENERAL FEATURES.

At present mining operations in the Chandalar Valley are confined to a rather small area whose central part is situated about 6 miles east of the upper end of Chandalar Lake. (See Pl. I, in pocket.) On the west this area is bounded by the north-south portion of the Chandalar Valley, on the north by a wide east-west valley now

drained by Lake and Grave creeks, on the east by the headwaters of McClennan and Big creeks, and on the south by Tobin Creek. As thus limited the area is about 10 miles in extent from north to south and the same from east to west and embraces about 100 square miles.

The chief features of this area are a rugged mountain mass, whose peaks are from 5,000 to 6,000 feet above sea level, and whose slopes are steep and deeply dissected by gulch valleys. The streams of these gulches are Big Creek and its tributary headwater stream St. Marys, Tobin Creek, Bowlder Creek, Big and Little Squaw creeks, and Big and Little McClennan creeks. They flow from the mountains in various directions and have concentrated along their courses more or less placer gold which is without doubt derived from the mineralized country rock into which the gulches have been eroded.

In a broad sense the Chandalar district may be considered an easterly continuation of the Koyukuk district. The same country rocks occur in both in the sections where gold has been found, their kinds, condition, and general stratigraphic relations being similar throughout a belt some 10 to 20 miles wide that extends from southwest to northeast across the region. The auriferous mineralization in the particular mountain mass here under consideration appears to have been associated with intrusive rocks, which at this locality are mostly diorites. There are apparently several of these intrusive masses, and they seem to be more or less accordant with the general strike, from southwest to northeast, of the country rocks which they cut. There are evidences of quartz mineralization in the schistose country rock about the borders of the intrusive masses. Several of these quartz bodies are 4 to 6 feet or more wide in their thickest parts and are known to have a more or less connected linear extent of several thousand feet. The directions of these lode zones do not appear to conform to the structural trends of the country rock, but rather to lie across the strike at large discordant angles. In general they extend from east to west.

In addition to the larger quartz-lode zones there are a number of small lenses scattered about in apparently a disconnected manner and a considerable number of veinlets at some localities. In general the quartz appears to be best developed around the borders of the larger dioritic intrusive masses, and while there are dikelike bodies of the same intrusive rock extending out from the larger masses the quartz mineralization does not appear to accompany these to any extent.

QUARTZ LODES.

Recent prospecting appears to reveal four principal quartz-lode zones, which extend across this mountain mass with general east-west trends in more or less connected form. It is thought that

these are practically continuous zones of fractures in the bedrock, but that the deposition of vein quartz, at least of quartz carrying gold, is not necessarily continuous along their whole extent but appears to occur more in the form of shootlike bodies. There is evidence that these zones have suffered shearing movements since some of the quartz was deposited along them, and it may be that the quartz is more or less cut off or squeezed out in places; also that the quartz was never deposited in a vein of more than a few inches thickness at other places. In some parts of these zones the fractured walls of country rock lie against each other, with practically no vein quartz deposited between their slickensided surfaces. In the larger bodies the quartz has been considerably crushed and recrystallized, which seems to indicate that considerable of the quartz was deposited before the latest shearing movements occurred.

The southernmost of these zones of more or less quartz-filled fractures extends across the upper part of Tobin Creek basin. The principal claims located in this basin are known as the Mikado group. To the east, in the valley of upper Big Creek, there is a body of gold-bearing quartz in the bed of the creek on Discovery placer claim, and a group of lode claims have been located along its westward trend, which extends toward the Mikado group in upper Tobin Creek basin. It is thought that these two groups of lode claims are along the same general mineralized zone, and that this zone may be continuous from the valley of Big Creek to the upper basin of Tobin Creek, a linear extent of 3 miles or more. Where shafts have been sunk along the quartz veins in Big and Tobin valleys it is found that they stand nearly vertical, their dip being 80° N.

On the Tobin, Little Mikado, and Mikado claims of the Mikado group the quartz has been exposed by open cuts in six places over a distance of 3,000 feet, and in all of these the quartz near the surface contains rich values in gold. Considerable development work has been done on the Little Mikado claim of this group. At about 20 feet from its west end line a shaft has been sunk on the vein to a depth of about 100 feet. The average thickness of this vein is about 4 feet, although there are some contractions and expansions along it. At a depth of 100 feet it is 3 feet 10 inches wide. It is reported that average assays from the quartz removed in sinking this shaft give $112 to the ton. In 1912 a tunnel was run on this claim to tap the vein upon which the shaft has been sunk. It is estimated that this tunnel will meet the vein in a distance of about 456 feet, at a depth of about 209 feet below the mouth of the shaft, which has already been sunk 100 feet. This tunnel is 4 by 6½ feet in cross section, and in September, 1912, had been driven 130 feet. Three men will continue it throughout the winter of 1912–13 under a contract which pays them about $8 a day for their labor.

Another zone of quartz mineralization lies about 2 miles north of the Mikado group. Three principal groups of claims are located along this zone. From west to east they are named the Kelty, Eneveloe, and Summit groups. The Kelty group is situated on the southwest headwaters of Big Squaw Creek and the Eneveloe group on the southeast headwaters of this stream. The Summit group extends along the divide between Big Creek and Little Squaw Creek. The veins along this zone dip about 65° S.

A tunnel on a line separating First Chance and Last Chance claims of the Eneveloe group has been driven 165 feet, to a point where its face is 125 feet below the surface. It is expected that this tunnel will tap a quartz vein about 200 feet from its mouth. On the Last Chance claim there is a surface outcrop of quartz which is reported to assay $198 to the ton. On the Woodchuck claim, which extends to the east from the Last Chance, a tunnel entrance has been opened on a vein of quartz that has a width of about 4 feet between well-defined walls. On the Eneveloe claim, which lies north of the Woodchuck claim, another body of quartz about 6 feet wide which carries considerable free gold has been prospected by three open pits.

On the Summit claim a shaft 54 feet deep has been sunk, and a tunnel has been run 72 feet along the vein. A sample from 5 feet of ore in the tunnel at a depth of 34 feet is reported to have assayed $54 to the ton. In the tunnel the vein was found to be from 1½ to 2 feet wide, and one rich lens of ore was found. The vein on this claim has been uncovered in four other places by shallow openings.

A third zone of quartz mineralization extends across the valley of Little Squaw Creek about three-fourths of a mile north of the Eneveloe group. As in that group, the dip of the vein is about 65° S. The principal claim, the Little Squaw, has a tunnel 87 feet long driven along the vein, reaching at its face a depth of 35 feet. About 50 tons of good ore are on the dump of this tunnel. Some of this ore has been run through a small stamp mill that has been erected near the mouth of Little Squaw Valley. It is reported that this ore assays $60 to the ton and that $38 to the ton of free gold was recovered on the plates of the stamp mill. A road has been built up the west side of Little Squaw Valley from this mill site to the Little Squaw claim.

A fourth group of lode claims is located on a zone of quartz outcrops about a mile north of the Little Squaw group. They extend across the west slope of the valley of Little Squaw Creek. Tunnels have been started on two of these claims.

The veins of the four belts of mineralization that have been located in this district are composed essentially of quartz, and so far as they have been developed appear to be chiefly of the fissure-vein type, although their form and extent as well-defined continuous quartz

bodies has not been conclusively demonstrated by the small amount of underground work done on them up to 1913. Further developments along the strike of the quartz bodies may show the veins in some parts of the fracture zones to be more like the kind termed stringer veins. This would not be surprising from the evidence of sheared displacements shown by the nature of the quartz that makes up the larger bodies which have been opened. However, so far as observed, the ore bodies are essentially fissure veins or shoots rather than stringer lodes.

A large part of the quartz is much crushed and recrystallized. Most of it is white in appearance, and composed of masses of interfering grains, without many cavities, into which crystalline prisms project. This massive quartz, however, has been much fractured into sheets, which, in general, lie parallel to the vein walls and each other. These sheets vary from an eighth of an inch up to several inches in thickness, and many of the thicker ones are broken into tablet-like pieces by cross fractures. Between the thicker sheets some of the thinner ones taper to knifelike edges, and many thin, small lenses of quartz occur along the fractures. Most of the fracture seams between the thin sheets and lenses of quartz would not be noticeable to the unaided eye if it were not for the presence of films of dark sulphides which are deposited along the fractures. In addition to the deformational sheeting of the quartz, which is apparently due primarily to shearing movements, there is some depositional banding present in the veins. These bands are fillings of quartz from 1 to 3 inches thick, which show quite perfect interlocking crystals along the centers of individual sheets. The evidence seems to indicate that they have been deposited along sheared fractures, whose faces have been sprung apart to the width of a few inches, instead of being closely appressed and slickensided by the shearing movements. None of these depositional seams appear to have been filled with the sulphide ores instead of quartz, although they are all open fractures in the older crushed and recrystallized quartz, which contains a considerable amount of the gold-bearing sulphides. This seems to indicate that much of the shearing has occurred since the sulphide minerals were first introduced. Many of the sheared faces of crushed and recrystallized quartz sheets show slickensided coatings or thin seams of sulphides.

The two most abundant gold-bearing sulphides appear to be sphalerite (zinc sulphide) and arsenopyrite (arsenical iron sulphide or mispickel). There are minor amounts of galena (lead sulphide) and stibnite (antimony sulphide), together with a little pyrite and chalcopyrite. All these sulphides are rather intimately associated with one another throughout the crushed, recrystallized,

and sheared quartz. These minerals occur both as small aggregates and blotches scattered through the more massive tablets of the recrystallized quartz sheets and as films and thin bands along the fractures between the sheets, especially between the thinner sheets. Free gold in flakes and specks may be observed mixed with the sulphides and scattered about in the quartz. Neither the sulphide mineral aggregates or the free gold appears to occur in solid forms or chunks of large size.

Within about 75 feet of the surface the ore is chiefly oxidized and the gold is probably for the most part free. Probably below the depth of 100 feet the ores will be found in a less oxidized condition.

The arsenical pyrite (mispickel) will probably be found to carry the highest values in gold, but the sphalerite (zinc blende or blackjack) will probably be more indicative of silver. Until thorough mill tests of the ore are made it will be impossible to state the gold tenor of the average ore. Probably one-third of the sulphide concentrates in a mill run of much of the ore will be sphalerite (zinc sulphide), with arsenopyrite and galena second and third in abundance. The sulphides sphalerite and galena generally tend more to silver than arsenopyrite or pyrite.

There seems to be little doubt that the most promise for the future of the Chandalar district is in its quartz lodes, but it requires a much larger initial investment of capital to develop lode deposits than placers, especially in a region so remote as this, where even rich shallow placers that require very little capital or machinery do not always yield adequate returns under present commercial conditions.

The Alaska Road Commission has taken steps to relieve the situation to some extent by laying out a winter sled trail from the settlement of Beaver, on the Yukon, over which supplies and machinery may be transported with greater facility than in the past. During the winter of 1909–10 a small prospecting stamp mill was hauled to Discovery claim on Big Creek, and an attempt was made to mine a quartz lode prospect on that claim, but this appears to have been discontinued. This mill has since been used for testing the ore from a vein on Squaw Creek.

PLACERS.

The placer gold in the gulches is without doubt derived from the erosion of the weathered vein material, and the fact that the placer gravels are not very rich, although they evidently represent the concentration of gold from the disintegration of a great thickness of country rock during a long period of erosion in a locality which does not appear to have been glaciated, may be used as evidence that the

gold-quartz veins contain only small amounts of gold. This, however, is not borne out by assays of the ore, for some remarkably rich gold quartz has been found in the prospects that have been opened.

There has been a little placer mining in the Chandalar district in the last 10 years, but the value of the total production does not exceed $60,000. Most of this gold has been taken from the head of Big Creek and from St. Marys Gulch. It is reported that in 1911 a shaft was sunk on Crooked Creek to a depth of 286 feet and one on Mammoth Creek to a depth of 172 feet, but that no workable placers were found.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

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The Eagle River region, southeastern Alaska, by Adolph Knopf, including detailed geologic and topographic maps. Bulletin 502, 1912, 61 pp.

The Sitka mining district, Alaska, by Adolph Knopf. Bulletin 504, 1912, 32 pp.

The earthquakes at Yakutat Bay, Alaska, in September, 1899, by R. S. Tarr and Lawrence Martin. Professional Paper 69, 1912, 135 pp.

Topographic maps.

Juneau special map; scale, 1: 62,500; by W. J. Peters. For sale at 10 cents each or $3 for 50.

Berners Bay special map; scale, 1 : 62,500; by R. B. Oliver. For sale at 10 cents each or $3 for 50.

Topographic map of the Juneau gold belt, Alaska. Contained in *Bulletin 287, Plate XXXVI, 1906. 75 cents. Not issued separately.

Kasaan Peninsula, Prince of Wales Island. No. 520–A; scale, 1 : 62,500; by R. H. Sargent, D. C. Witherspoon, and J. W. Bagley. For sale at 10 cents each or $3 for 50.

Copper Mountain and vicinity, Prince of Wales Island, scale, 1: 62,500; by R. H. Sargent. For sale at 10 cents each or $3 for 50.

CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

*The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall. Professional Paper 15, 1903, 71 pp. Contains map of Prince William Sound and Copper River region; scale, 12 miles=1 inch. 30 cents.

*Bering River coal field, by G. C. Martin. In Bulletin 259, 1905, pp. 140–150. 15 cents.

*Cape Yaktag placers, by G. C. Martin In Bulletin 259, 1905, pp. 88–89. 15 cents.

*Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin 259, 1905, pp. 128–139. 15 cents. (Abstract from Bulletin 250.)

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.

Geology of the central Copper River region, Alaska, by W. C. Mendenhall. Professional Paper 41, 1905, 133 pp.

Copper and other mineral resources of Prince William Sound, by U. S. Grant. In Bulletin 284, 1906, pp. 78–87.

Distribution and character of the Bering River coal, by G. C. Martin. In Bulletin 284, 1906, pp. 65–76.

Petroleum at Controller Bay, by G. C. Martin. In Bulletin 314, 1907, pp. 89–103.

Geology and mineral resources of Controller Bay region, by G. C. Martin. Bulletin 335, 1908, 141 pp.

*Notes on copper prospects of Prince William Sound, by F. H. Moffit. In Bulletin 345, 1908, pp. 176–178. 45 cents.

*Mineral resources of the Kotsina and Chitina valleys, Copper River region, by F. H. Moffit and A. G. Maddren. In Bulletin 345, 1908, pp. 127–175. 45 cents.

Mineral resources of the Kotsina-Chitina region, by F. H. Moffit and A. G. Maddren. Bulletin 374, 1909, 103 pp.

*Copper mining and prospecting on Prince William Sound, by U. S. Grant and D. F. Higgins, jr. In Bulletin 379, 1909, pp. 87–96. 50 cents.

*Gold on Prince William Sound, by U. S. Grant. In Bulletin 379, 1909, p. 97. 50 cents.

*Mining in the Kotsina-Chitina, Chistochina, and Valdez Creek regions, by F. H. Moffit. In Bulletin 379, 1909, pp. 153–160. 50 cents.

*Mineral resources of the Nabesna-White River district, by F. H. Moffit and Adolph Knopf. In Bulletin 379, 1909, pp. 161–180. 50 cents.

Mineral resources of the Nabesna-White River district, by F. H. Moffit and Adolph Knopf; with a section on the Quaternary, by S. R. Capps. Bulletin 417, 1910, 64 pp.

Mining in the Chitina district, by F. H. Moffit. In Bulletin 442, 1910, pp. 158–163.

Mining and prospecting on Prince William Sound, by U. S. Grant. In Bulletin 442. 1910, pp. 164–165.

Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 443, 1910, 89 pp.
Geology and mineral resources of the Nizina district, Alaska, by F. H. Moffit and S. R. Capps. Bulletin 448, 1911, 111 pp.
Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts, by F. H. Moffit; including geologic and topographic reconnaissance maps. Bulletin 498, 1912, 82 pp.
The upper Susitna and Chistochina districts, by F. H. Moffit. In Bulletin 480, 1911, p. 127.
*The Taral and Bremner districts, by F. H. Moffit. In Bulletin 520, 1912, pp. 93–104. 50 cents.
*The Chitina district, by F. H. Moffit. In Bulletin 520, 1912, pp. 105–107. 50 cents.
*Gold deposits near Valdez, by A. H. Brooks. In Bulletin 520, 1912, pp. 108–130. 50 cents.
Coastal glaciers of Prince William Sound and Kenai Peninsula, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 526, 1913, 84 pp.
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Topographic maps.

Copper and upper Chistochina rivers; scale, 1:250,000; by T. G. Gerdine. Contained in Professional Paper 41. Not issued separately.
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Controller Bay region; No. 601 A; scale, 1:62,500; by E. G. Hamilton. Price 35 cents a copy or $21 per hundred.
Headwater regions of Gulkana and Susitna rivers; scale, 1:250,000; by D. C. Witherspoon and C. E. Giffin. Contained in Bulletin 498. Not published separately.

COOK INLET AND SUSITNA REGION.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.
*Coal resources of southwestern Alaska, by R. W. Stone. In Bulletin 259, 1905, pp. 151–171. 15 cents.
*Gold placers of Turnagain Arm, Cook Inlet, by F. H. Moffit. In Bulletin 259, 1905, pp. 90–99. 15 cents.
*Mineral resources of the Kenai Peninsula: Gold fields of the Turnagain Arm region, by F. H. Moffit, pp. 1–52; Coal fields of the Kachemak Bay region, by R. W. Stone, pp. 53–73. Bulletin 277, 1906, 80 pp. 25 cents.
Preliminary statement on the Matanuska coal field, by G. C. Martin. In Bulletin 284, 1906, pp. 88–100.
*A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. Bulletin 289, 1906, 36 pp.
Reconnaissance in the Matanuska and Talkeetna basins, by Sidney Paige and Adolph Knopf. In Bulletin 314, 1907, pp. 104–125.
Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska, by Sidney Paige and Adolph Knopf. Bulletin 327, 1907, 71 pp.
*Notes on geology and mineral prospects in the vicinity of Seward, Kenai Peninsula, by U. S. Grant. In Bulletin 379, 1909, pp. 98–107. 50 cents.
Preliminary report on the mineral resources of the southern part of Kenai Peninsula, by U. S. Grant and D. F. Higgins. In Bulletin 442, 1910, pp. 166–178.
Outline of the geology and mineral resources of the Iliamna and Clark lakes region, by G. C. Martin and F. J. Katz. In Bulletin 442, 1910, pp. 179–200.
Gold placers of the Mulchatna, by F. J. Katz. In Bulletin 442, 1910, pp. 201–202.
The Mount McKinley region, by A. H. Brooks, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle. Professional Paper 70, 1911, 234 pp.
A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp.
Geology and coal fields of the lower Matanuska Valley, Alaska, by G. C. Martin and F. J. Katz; including detailed geologic and topographic maps. Bulletin 500, 1912, 98 pp.
*Gold deposits of the Seward-Sunrise region, Kenai Peninsula, by B. L. Johnson. In Bulletin 520, 1912, pp. 131–173. 50 cents.

*Gold placers of the Yentna district, by S. R. Capps. In Bulletin 520, 1912. pp. 174–200. 50 cents.
The Yentna district, Alaska, by S. R. Capps. Bulletin 534, 1913, 75 pp.
Preliminary report on a detailed survey of part of the Matanuska coal fields, by G. C. Martin. In Bulletin 480, 1911, p. 135.
A reconnaissance of the Willow Creek gold region, by F. J. Katz. In Bulletin 480, 1911, p. 152.

Topographic maps.

*Kenai Peninsula, northern portion; scale, 1:250,000; by E. G. Hamilton. Contained in Bulletin 277. 25 cents. Not published separately.
Reconnaissance map of Matanuska and Talkeetna region; scale, 1:250,000; by T. G. Gerdine and R. H. Sargent. Contained in Bulletin 327. Not published separately.
Mount McKinley region; scale, 1:625,000; by D. L. Reaburn. Contained in Professional Paper 70. Not published separately.
Lower Matanuska Valley; scale, 1:62,500; by R. H. Sargent. Contained in Bulletin 500. Not published separately.

SOUTHWESTERN ALASKA.

*Gold mine on Unalaska Island, by A. J. Collier. In Bulletin 259, 1905, pp. 102–103. 15 cents.
*Gold deposits of the Shumagin Islands, by G. C. Martin. In Bulletin 259, 1905. pp. 100–101. 15 cents.
*Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin 259, 1905, pp. 128–139. 15 cents. (Abstract from Bulletin 250.)
The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.
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*Mineral resources of southwestern Alaska, by W. W. Atwood. In Bulletin 379, 1909, pp. 108–152. 50 cents.
Geology and mineral resources of parts of Alaska Peninsula, by W. W. Atwood. Bulletin 467.
Outline of the geology and mineral resources of the Iliamna and Clark Lake region, by G. C. Martin and F. J. Katz. In Bulletin 442, 1910, pp. 179–200.
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The Balboa-Herendeen Bay and Unga Island region; scale, 1:250,000; by H. M. Eakin. Contained in Bulletin 467. Not issued separately.
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YUKON BASIN.

*The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin 218, 1903, 71 pp. 15 cents.
*The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, by L. M. Prindle. Bulletin 251, 1905, 89 pp. 35 cents.
Yukon placer fields, by L. M. Prindle. In Bulletin 284, 1906, pp. 109–131.
Reconnaissance from Circle to Fort Hamlin, by R. W. Stone. In Bulletin 284, 1906, pp. 128–131.
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The Circle precinct, Alaska, by A. H. Brooks. In Bulletin 314, 1907, pp. 187–204.
*The Yukon-Tanana region, Alaska; description of the Fairbanks and Rampart quadrangles, by L. M. Prindle, F. L. Hess, and C. C. Covert. Bulletin 337, 1908, 102 pp. 25 cents.
*Occurrence of gold in the Yukon-Tanana region, by L. M. Prindle. In Bulletin 345, 1908, pp. 179–186. 45 cents.
*The Fortymile gold-placer district, by L. M. Prindle. In Bulletin 345, 1908, pp. 187–197. 45 cents.

*Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp. 25 cents.
*Water supply of the Fairbanks district in 1907, by C. C. Covert. In Bulletin 345, 1908, pp. 198–205. 45 cents.
The Fortymile quadrangle, by L. M. Prindle. Bulletin 375, 1909, 52 pp.
Water-supply investigations in Yukon-Tanana region, 1906–1908, by C. C. Covert and C. E. Ellsworth. Water-Supply Paper 228, 1909, 108 pp.
*The Fairbanks gold-placer region, by L. M. Prindle and F. J. Katz. In Bulletin 379, 1909, pp. 181–200. 50 cents.
*Water supply of the Yukon-Tanana region, 1907–8, by C. C. Covert and C. E. Ellsworth. In Bulletin 379, 1909, pp. 201–228. 50 cents.
*Gold placers of the Ruby Creek district, by A. G. Maddren. In Bulletin 379, 1909, pp. 229–233. 50 cents.
*Placers of the Gold Hill district, by A. G. Maddren. In Bulletin 379, 1909, pp. 234–237. 50 cents.
*Gold placers of the Innoko district, by A. G. Maddren. In Bulletin 379, 1909, pp. 238–266. 50 cents.
The Innoko gold-placer district, Alaska, with accounts of the central Kuskokwim Valley and the Ruby Creek and Gold Hill placers, by A. G. Maddren. Bulletin 410, 1910, 87 pp.
Sketch of the geology of the northeastern part of the Fairbanks quadrangle, by L. M. Prindle. In Bulletin 442, 1910, pp. 203–209.
The auriferous quartz veins of the Fairbanks district, by L. M. Prindle. In Bulletin 442, 1910, pp. 210–229.
Placer mining in the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 230–245.
Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district, by B. L. Johnson. In Bulletin 442, 1910, pp. 246–250.
Water supply of the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 251–283.
The Koyukuk-Chandalar gold region, by A. G. Maddren. In Bulletin 442, 1910, pp. 284–315.
Placer mining in the Yukon-Tanana region, by C. E. Ellsworth and G. L. Parker. In Bulletin 480, 1911, p. 172.
Water supply of the Yukon-Tanana region, 1910, by C. E. Ellsworth and G. L. Parker. In Bulletin 480, 1911, p. 217.
Mineral resources of the Bonnifield region, by S. R. Capps. In Bulletin 480, 1911, p. 235.
Gold placer mining developments in the Innoko-Iditarod region, by A. G. Maddren. In Bulletin 480, 1911, p. 270.
*Placer mining in the Fortymile and Seventymile river districts, by E. A. Porter. In Bulletin 520, 1912, pp. 211–218. 50 cents.
*Water supply of the Fortymile, Seventymile, and Eagle districts, by E. A. Porter. In Bulletin 520, 1912, pp. 219–239. 50 cents.
*Placer mining in the Fairbanks and Circle districts, by C. E. Ellsworth. In Bulletin 520, 1912, pp. 240–245. 50 cents.
*Water supply of the Fairbanks, Salchaket, and Circle districts, by C. E. Ellsworth. In Bulletin 520, 1912, pp. 246–270. 50 cents.
*The Rampart and Hot Springs regions, by H. M. Eakin. In Bulletin 520, 1912, pp. 271–286. 50 cents.
*The Ruby placer district, by A. G. Maddren. In Bulletin 520, 1912, pp. 287–296. 50 cents.
*Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River, by L. M. Prindle and J. B. Mertie, jr. In Bulletin 520, 1912, pp. 201–210. 50 cents.
The Bonnifield region, Alaska, by S. R. Capps; including geologic and topographic reconnaissance maps. Bulletin 501, 1912, 162 pp.
A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp.
A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle; with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith. Bulletin 525, 1913, 220 pp.
The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp.
A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle. Bulletin 538. (In preparation.)
The Iditarod-Ruby region, Alaska, by H. M. Eakin, with geologic and topographic reconnaissance maps. Bulletin ——. (In preparation.)

Topographic maps.

Fortymile quadrangle; No. 640; scale, 1: 250,000; by E. C. Barnard. Price, 10 cents a copy or $3 for 50.

Fairbanks quadrangle; No. 642; scale, 1: 250,000; by T. G. Gerdine, D. C. Witherspoon, and R. B. Oliver. Price, 20 cents a copy or $6 for 50.

Rampart quadrangle; No. 643; scale, 1: 250,000; by D. C. Witherspoon and R. B. Oliver. Price, 20 cents a copy or $6 for 50.

Fairbanks district; No. 642A; scale, 1: 62,500; by T. G. Gerdine and R. H. Sargent. Price, 20 cents a copy or $6 for 50.

*Yukon-Tanana region, reconnaissance map of; scale, 1: 625,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. 35 cents. Not published separately.

*Fairbanks and Birch Creek districts, reconnaissance maps of; scale, 1: 250,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. 35 cents. Not issued separately.

Circle quadrangle, Yukon-Tanana region; scale, 1: 250,000; by D. C. Witherspoon. Price 50 cents a copy. Also contained in Bulletin 295.

SEWARD PENINSULA.

*A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900, by A. H. Brooks, G. B. Richardson, and A. J. Collier. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 180 pp. 50 cents.

*A reconnaissance in the Norton Bay region, Alaska, in 1900, by W. C. Mendenhall. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 38 pp. 50 cents.

*A reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. Professional Paper 2, 1902, 70 pp. 30 cents.

*The tin deposits of the York region, Alaska, by A. J. Collier. Bulletin 229, 1904, 61 pp. 15 cents.

*Recent developments of Alaskan tin deposits, by A. J. Collier. In Bulletin 259, 1905, pp. 120–127. 15 cents.

*The Fairhaven gold placers of Seward Peninsula, by F. H. Moffit. Bulletin 247, 1905, 85 pp. 40 cents.

The York tin region, by F. L. Hess. In Bulletin 284, 1906, pp. 145–157.

Gold mining on Seward Peninsula, by F. H. Moffit. In Bulletin 284, 1906, pp. 132–141.

The Kougarok region, by A. H. Brooks. In Bulletin 314, 1907, pp. 164–181.

*Water supply of Nome region, Seward Peninsula, Alaska, 1906, by J. C. Hoyt and F. F. Henshaw. Water-Supply Paper 196, 1907, 52 pp. 15 cents.

Water supply of the Nome region, Seward Peninsula, 1906, by J. C. Hoyt and F. F. Henshaw. In Bulletin 314, 1907, pp. 182–186.

The Nome region, by F. H. Moffit. In Bulletin 314, 1907, pp. 126–145.

Gold fields of the Solomon and Niukluk river basins, by P. S. Smith. In Bulletin 314, 1907, pp. 146–156.

Geology and mineral resources of Iron Creek, by P. S. Smith. In Bulletin 314, 1907, pp. 157–163.

The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin 328, 1908, 343 pp.

*Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin 345, 1908, pp. 206–250. 45 cents.

*The Seward Peninsula tin deposits, by Adolph Knopf. In Bulletin 345, 1908, pp. 251–267. 45 cents.

*Mineral deposits of the Lost River and Brooks Mountain regions, Seward Peninsula, by Adolph Knopf. In Bulletin 345, 1908, pp. 268–271. 45 cents.

*Water supply of the Nome and Kougarok regions, Seward Peninsula, in 1906–7, by F. F. Henshaw. In Bulletin 345, 1908, pp. 272–285. 45 cents.

*Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp. 25 cents.

Geology of the Seward Peninsula tin deposits, by Adolph Knopf. Bulletin 358, 1908, 72 pp.

*Recent developments in southern Seward Peninsula, by P. S. Smith. In Bulletin 379, 1909, pp. 267–301. 50 cents.

*The Iron Creek region, by P. S. Smith. In Bulletin 379, 1909, pp. 302–354. 50 cents.

*Mining in the Fairhaven precinct, by F. F. Henshaw. In Bulletin 379, 1909, pp. 355–369. 50 cents.

*Water-supply investigations in Seward Peninsula in 1908, by F. F. Henshaw. In Bulletin 379, 1909, pp. 370–401. 50 cents.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, by P. S. Smith. Bulletin 433, 1910, 227 pp.
Mineral resources of the Nulato-Council region, by P. S. Smith and H. M. Eakin. In Bulletin 442, 1910, pp. 316–352.
Mining in Seward Peninsula, by F. F. Henshaw. In Bulletin 442, 1910, pp. 353–371.
Water-supply investigations in Seward Peninsula in 1909, by F. F. Henshaw. In Bulletin 442, 1910, pp. 372–418.
A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, by P. S. Smith and H. M. Eakin. Bulletin 449, 1911, 146 pp.
*Notes on mining in Seward Peninsula, by P. S. Smith. In Bulletin 520, 1912, pp. 339–344.
Geology of the Nome and Grand Central quadrangles, Alaska, by F. H. Moffit. Bulletin 533, 1913, 140 pp.
Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology, by P. S. Smith, and a description of methods of placer mining, by Alfred H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp.

Topographic maps.

The following maps are for sale at 10 cents a copy or $3 for 50:

Casadepaga quadrangle, Seward Peninsula; No. 646 C; scale, 1:62,500; by T. G. Gerdine.
Grand Central quadrangle, Seward Peninsula; No. 646 A; scale, 1:62,500; by T. G. Gerdine.
Nome quadrangle, Seward Peninsula; No. 646 B; scale, 1:62,500; by T. G. Gerdine.
Solomon quadrangle, Seward Peninsula; No. 646 D; scale, 1:62,500; by T. G. Gerdine.

The three following maps are for sale at 50 cents a copy or $15 for 50:

Seward Peninsula, northeastern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, northwestern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, southern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.

Seward Peninsula, southeastern portion of, topographic reconnaissance of; scale, 1:250,000. Contained in Bulletin 449. Not published separately.

NORTHERN ALASKA.

*A reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. Professional Paper 10, 1902, 68 pp. 30 cents.
*A reconnaissance in northern Alaska across the Rocky Mountains, along the Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901, by F. C. Schrader and W. J. Peters. Professional Paper 20, 1904, 139 pp. 40 cents.
*Coal fields of the Cape Lisburne region, by A. J. Collier. In Bulletin 259, 1905, pp. 172–185. 15 cents.
*Geology and coal resources of Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp. 15 cents.
The Shungnak region, Kobuk Valley, by P. S. Smith and H. M. Eakin. In Bulletin 480, 1911, pp. 271–305.
The Squirrel River placers, by P. S. Smith. In Bulletin 480, 1911, pp. 306–319.
*Geologic investigations along the Canada-Alaska boundary, by A. G. Maddren. In Bulletin 520, 1912, pp. 297–314. 50 cents.
*The Alatna-Noatak region, by P. S. Smith. In Bulletin 520, 1912, pp. 315–338. 50 cents.
The Noatak-Kobuk region, by P. S. Smith. Bulletin 536. (In preparation.)

Topographic maps.

*Fort Yukon to Kotzebue Sound, reconnaissance map of; scale, 1:1,200,000; by D. L. Reaburn. Contained in Professional Paper 10. 30 cents. Not published separately.
*Koyukuk River to mouth of Colville River, including John River; scale, 1:1,200,000; by W. J. Peters. Contained in Professional Paper 20. 40 cents. Not published separately.

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GEOLOGY
OF THE
NOME AND GRAND CENTRAL QUADRANGLES
ALASKA

BY

FRED H. MOFFIT

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CONTENTS.

ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

The investigation of the mineral resources of Seward Peninsula by the United States Geological Survey was begun in 1899 with a brief examination of the then newly discovered gold placers near Nome. During the succeeding five years geologic and topographic reconnaissance surveys (scale 4 miles to 1 inch) were carried over nearly the entire peninsula. There still remained a small area north of Norton Bay, which was surveyed in 1909, thus completing the reconnaissance mapping of the peninsula.

Although these reconnaissance surveys have been of great value, it was recognized that a full understanding of the problems of stratigraphic and economic geology of the district could be achieved only by means of detailed surveys. Moreover, topographic maps of a larger scale were needed for the use of a community engaged in many engineering projects. Accordingly detailed topographic surveys (scale 1 mile to the inch, with 25-foot contours) of the Nome and Grand Central quadrangles were made in 1904 and of the Solomon and Casadepaga quadrangles in 1905.

Detailed geologic surveys and investigations were made at Nome in 1905 and 1906 and at Solomon in 1907 and 1908. After the completion of the surveys of the Nome and Grand Central quadrangles it was found that many geologic problems concerning those areas were so complex as to defy solution unless the investigations were extended into adjoining fields, and therefore the publication of the report was deferred until the Solomon and Casadepaga quadrangles could be surveyed. The expectation that the information thus gained would help to solve the problems referred to was, however, only in part fulfilled. It was found that the stratigraphic results obtained in the Solomon region could be correlated with the geology of the Nome region only by surveying the intermediate area, a belt some 30 miles in width. Unfortunately the urgent need for investigations in other parts of Alaska made it necessary to defer the making of any more detailed surveys in Seward Peninsula. These conditions

left but two courses open in regard to the results obtained from the survey of the Nome and Grand Central quadrangles—either to defer their publication indefinitely or to print the report embodying them in essentially its original form, with only an incomplete statement of detailed stratigraphy and structure. In view of the importance of the mining interests within the area described, it was determined to adopt the latter course. The reader of this report, therefore, must not expect to find herein an exhaustive treatment of all the many geologic problems of the region.

In justice to Mr. Moffit it should be stated that since the completion in 1906 of the field work on which this report is based, he has made five other important investigations in different parts of Alaska and published the results. His assistants, Mr. Hess and Mr. Smith, have also been transferred to other fields of investigation. Meanwhile as mining advanced new information regarding the occurrence of the alluvial gold has become available, which should properly find place in this report. Therefore there has been good reason for the unfortunate delay in issuing this volume. This delay has worked no great hardship to the mining industry, for most of the accounts of the gold placers here presented have been published from time to time in other reports. It seemed desirable, however, to bring together in one volume all the information at hand regarding the occurrence of the auriferous gravels. Much of this is now only of scientific interest, as many of the rich placers have been worked out. A knowledge of their mode of occurrence will be valuable, however, not only in this but in other regions, in helping to establish the natural laws which determine the distribution of gold in alluvium. As a record of one of the richest placer camps of Alaska, this report will have permanent value.

Bonanza mining in the Nome region, which has produced over $50,000,000 worth of gold, is now nearly a thing of the past. There are still, however, large bodies of auriferous gravels, many of which can be profitably exploited. It is not unlikely that in the future more gold will be won from these deposits than has been mined in the past. Of lode mining less definite statement is possible, but it may be said that the field is well worthy of careful prospecting for vein deposits.

GEOLOGY OF THE NOME AND GRAND CENTRAL QUADRANGLES, ALASKA.

By Fred H. Moffit.

INTRODUCTION.

FIELD WORK.

The field work on which the following descriptions are based was begun in 1905 and completed in 1906. During the first year the field investigation was carried on by Frank L. Hess and Fred H. Moffit, but in the following year Mr. Hess was unable to continue the work, and his place was taken by Philip S. Smith. Publication of the results was delayed for various reasons until it became necessary to rewrite a considerable part of the manuscript, in order that the geologic descriptions might receive such additions and corrections as later detailed work in neighboring areas showed to be necessary and that later mining developments might be given. Such delays necessarily detract from the interest and value of geologic reports on regions of gold placers like that at Nome, where changes follow one another rapidly, but fortunately many of the conclusions of the work have already been given in the reports on progress of investigations in Alaska in 1905 and 1906.[1]

The earliest study of the Nome gold placers undertaken by the Federal Survey was made by Brooks and Schrader in 1899. They spent a portion of October of that year at Nome and vicinity and published a brief preliminary report on that region. In the following year (1900) a reconnaissance survey of the southwestern part of Seward Peninsula was made by Brooks, assisted by Collier and Richardson. The area studied included the region south of Koyuk River and the depression in which lie Kuzitrin River and Imuruk Basin, but the eastern portion was examined in a more hasty manner than the western and central portions. The published report of this work is the most important contribution that has been made to the geologic literature of the Nome region, for it laid the foundation for all subsequent work.

[1] Bull. U. S. Geol. Survey No. 284, 1906; No. 314, 1907.

A further brief study of the region was made by Collier and Hess in 1903 in the course of an investigation of various placer districts of southern Seward Peninsula. During the summer they visited the gold-producing districts near Nome, Teller, Council, and Solomon, also a part of the Kougarok region. They determined the presence of tin in its bedrock source and were present when the first location of tin-bearing ledges was made in Seward Peninsula.

The next work of the Federal Survey at Nome was that of 1905 and 1906, which is the basis of the present paper. Since 1906 Smith, in connection with detailed geologic work in the Solomon and Casadepaga districts, has investigated the development of lode and placer-mining properties in the vicinity of Nome, and Kindle has made at various localities on Seward Peninsula paleontologic studies that have increased the knowledge of the stratigraphy.

PUBLISHED REPORTS.

The published results of the studies that deal more particularly with the Nome district are contained in the following papers:

SCHRADER, F. C., and BROOKS, A. H., Preliminary report on the Cape Nome gold region, Alaska: Special publication U. S. Geol. Survey, 1900.

BROOKS, A. H., RICHARDSON, G. B., and COLLIER, A. J., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900: Special publication U, S. Geol. Survey, 1901.

MOFFIT, F. H., Gold mining on Seward Peninsula: Bull. U. S. Geol. Survey No. 284, 1906, pp. 132–144.

——— The Nome region: Bull. U. S. Geol. Survey No. 314, 1907, pp. 126–145.

COLLIER, A. J., HESS, F. L., SMITH, P. S., and BROOKS, A. H., The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908.

SMITH, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey No. 345, 1908, pp. 206–250.

——— Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, pp. 267–301.

——— Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 433, 1910. This paper does not deal directly with the Nome region, but treats many of the same problems that are found there.

PURINGTON, C. W., Methods and costs of gravel and placer mining in Alaska: Bull. U. S. Geol. Survey No. 263, 1905. This paper deals with the commercial rather than the geologic side of mining in Alaska and gives considerable attention to the Nome district.

In 1906 the investigation of the water supply of the Nome district was begun, and its results have been published as follows:

HOYT, J. C., and HENSHAW, F. F., Water supply of Nome region, Seward Peninsula, 1906: Bull. U. S. Geol. Survey No. 314, 1907, pp. 182–186. Also Water-Supply Paper No. 196.

HENSHAW, F. F., Water supply of the Nome and Kougarok regions, Seward Peninsula, 1906–7: Bull. U. S. Geol. Survey No. 345, 1908, pp. 272–285.

HENSHAW, F. F., Water-supply investigations in Alaska, 1906–7; Water-supply Paper U. S. Geol. Survey No. 218, 1908.

——— Water supply investigations in Seward Peninsula in 1908: Bull. U. S. Geol. Survey No. 379, 1909, pp. 370–399.

——— Water-supply investigations in Seward Peninsula in 1909: Bull. U. S. Geol. Survey No. 442, 1910, pp. 372–418.

HENSHAW, F. F., and PARKER, G. L., Surface water supply of Seward Peninsula, Alaska: Water-Supply Paper U. S. Geol. Survey No. 314, 1913.

LOCATION AND AREA OF THE DISTRICT.

The district under consideration is situated in the south-central part of Seward Peninsula (fig. 1), and is included between meridians 165° and 165° 30′ west longitude and parallels 64° 25′ and 64° 57′ north latitude. It has a width from east to west of almost 15 miles, and extends north from its most southern point, Cape Nome, a distance of about 35 miles. Its area is thus approximately 525 square miles. This district is herein represented on two topographic maps (Pls. I and II, in pocket).

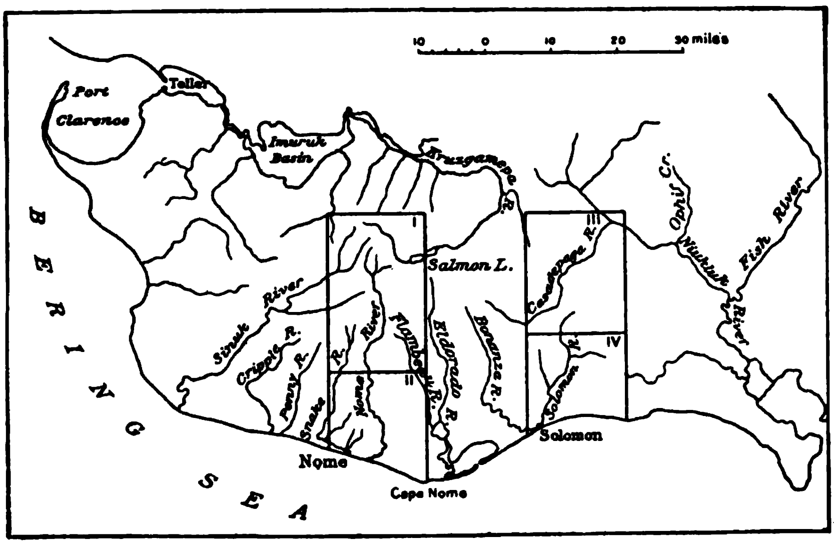

FIGURE 1.—Index map of southern Seward Peninsula, showing areas represented by detailed topographic and geologic maps. I, Grand Central quadrangle; II, Nome quadrangle; III, Casadepaga quadrangle; IV, Solomon quadrangle.

Seward Peninsula projects west from the main body of Alaska between Bering Sea and the Arctic Ocean. Its northern coast touches the Arctic Circle; and Cape Prince of Wales, the most westerly point of the peninsula and of the North American mainland, approaches within 60 miles of East Cape, Siberia. The Arctic Ocean and Kotzebue Sound on the north and Bering Sea and Norton Sound on the south almost surround it, and give propriety to the name peninsula. Its coast line is monotonous. In places the highlands reach

the sea, but for the most part its shores are bordered by low sand and gravel plains that slope gradually up to the hills. Lagoons cut off from the ocean by sand bars form a notable feature of the Arctic coast, but are less numerous on the side toward Bering Sea. Shallow water extends far off shore, and the landing of freight and passengers is difficult in bad weather, for ocean steamers are obliged to anchor a mile or more from the beach, where deep water gives them safety. Port Clarence is the only protected harbor of the whole coast, and is so situated as to be of comparatively little use to shipping.

Bering Sea is the chief avenue of communication with the outside world, but is closed to navigation for nearly seven months of the year. During this season no supplies are received at Nome, although mail is brought in over the winter trail from Valdez. Nome, the principal mining center of Seward Peninsula and the second largest town in Alaska, is about 2,300 statute miles from Seattle by direct water route. It is the distributing point of supplies for almost the entire peninsula, as nearly all freight not destined for Nome itself is here transferred to smaller vessels or unloaded for overland shipment.

Nome River, which flows southward through the middle of the area from a point within a few miles of the northern boundary, furnishes an easy route of communication with many of the producing creeks as well as with the interior of the peninsula. The track of the Seward Peninsula Railway follows its valley northward, and, crossing the divide to Salmon Lake, continues to the Kuzitrin by way of the Kruzgamepa or Pilgrim River valley. A smaller stream, Snake River, at whose mouth Nome is situated, affords a highway to the southwestern part of the district, and the southeastern and eastern parts may be reached by wagon trail to Osborn and Buster creeks. Until the wagon road leading north from Nome to the head of Dry Creek was constructed in 1906, the stream beds and the ridges were the regular routes of travel, and they still continue to be the only practicable ways of getting into much of the region.

TOPOGRAPHY.

GENERAL FEATURES OF SEWARD PENINSULA.

Seward Peninsula is an ancient land mass whose surface has been exposed to the agents of erosion so long that it has lost most of its youthful angularity and appears now with the smooth contours that indicate great age. Broad rounded hilltops and wide shallow valleys characterize the region. This kind of topography prevails through most of the northern half of the peninsula and in much of the southern part, although in the latter it is modified by a chain of younger rugged mountains, which lies nearly parallel to and

just south of the east-west axis of the peninsula. This chain is composed of the Kigluaik and Bendeleben mountains, with which the Darby Mountains were formerly included, although their direction is more nearly north and south than east and west and they probably do not belong to the Kigluaik-Bendeleben chain. The Kigluaik and Bendeleben mountains are separated from the northern half of the peninsula by a depression formed by the valleys of Kuzitrin and Koyuk rivers, two streams that with their tributaries drain most of the interior region. These rivers have their sources in the broad, flat lava fields north of the Bendeleben Mountains. The Kuzitrin flows west through Imuruk Basin to Port Clarence, but the Koyuk takes a southeasterly course to Norton Bay. Several smaller streams, including the Kiwalik, Kugruk, Inmachuk, and Goodhope, rise in this same lava field and with Serpentine River, farther west, flow north to the Arctic Ocean. The largest river of the south coast is the Niukluk, but Solomon, Nome, Snake, and Sinuk rivers, although much smaller, are important because of their gold-bearing gravels.

RELIEF.

Three types of topography—coastal plain, dissected upland, and rugged mountain mass—are represented in the Nome and Grand Central quadrangles (Pls. I and II, in pocket).

A narrow coastal plain, the Nome tundra (Pl. VI, *A*), slopes gently upward from Bering Sea to the foot of the hills that border the coast. Near Nome this plain has a width of nearly 4 miles from north to south, but it narrows toward the east till it disappears at Cape Nome. Its surface is not a plane, for it has been cut by many streams and its former more nearly uniform slopes have given place to many irregularities, which, however, when viewed in a large way are not great.

A second type of topography is seen in the region between the Nome tundra and the east-west depression formed by the valleys of Sinuk River and Salmon Lake. This region for the most part is one of rounded hills and broad ridges whose altitudes increase with considerable regularity from south to north. In the southern part of the area the higher summits stand at an elevation of about 1,000 feet above the sea, but in the northern part the average height is not far from 2,000 feet, although one or two of the highest hills reach or exceed 2,600 feet. This area is part of an elevated land mass whose original surface has been destroyed by the cutting of numerous streams and the weathering action of sun, frost, and rain through countless ages. It is a dissected plateau whose early form is suggested by the accordance in elevation of those parts that have resisted the destroying agents most strongly.

The third type of topography is found in the east-west range of the Kigluaik or Sawtooth Mountains, only a small portion of which is

shown on the Grand Central map (Pl. II, in pocket). This is a region of jagged peaks and sharp ridges separated by steep-walled glaciated valleys (Pls. VI, *B;* VIII, *A*, p. 24; XI, p. 62). Many of the summits have elevations greater than 3,000 feet. Mount Osborn (4,126 feet), the highest point on Seward Peninsula, stands at the head of Grand Central River, 3 miles beyond the northern limit of the quadrangle. Moderate southern slopes and precipitous northern slopes are prominent features of these mountains and help to make them a great storehouse for snows that supply water to numerous streams throughout the summer, as the lofty southern valley walls protect the snow from the sun and preserve it from rapid melting in the spring.

DRAINAGE.

Nearly all the larger streams of southwestern Seward Peninsula originate in or near the Kigluaik Mountains. One of them, Nome River, lies wholly within the area under consideration and drains the larger portion of it. A second river, the Sinuk (often called the Sinrock), with its southern branch, Stewart River, drains the northwestern part of the area and flows southwest to Bering Sea. Grand Central River and its tributaries drain the northeastern part. The Grand Central flows into Salmon Lake, whose waters are carried north around the east end of the Kigluaik Mountains and into Imuruk Basin by Kruzgamepa River.

The other larger streams originating within the plateau region are Snake River, which lies west of and parallel to Nome River, and Flambeau River, whose upper part only is shown on the maps. Nome and Snake rivers flow in meandering courses through broad gravel-floored valleys, but with few exceptions the small streams outside of the coastal plain flow in narrow steep-walled valleys. One very noticeable difference between these streams and those of similar regions in more temperate climates is that few of them are ever dry in summer. Melting ice beneath the blanket of moss supplies some water throughout the warmer season, although most of the water from this source is probably lost by evaporation. The moss itself absorbs the rainfall like a sponge and prevents a rapid run-off. When nearly saturated, however, the moss has a much lessened effect in holding water.

DESCRIPTIVE GEOLOGY.

OUTLINE OF THE GEOLOGY OF SEWARD PENINSULA.

Most of the rocks of Seward Peninsula are of sedimentary origin, and are highly metamorphosed. They comprise chiefly schists of various kinds and much-altered limestones. Plate V shows the

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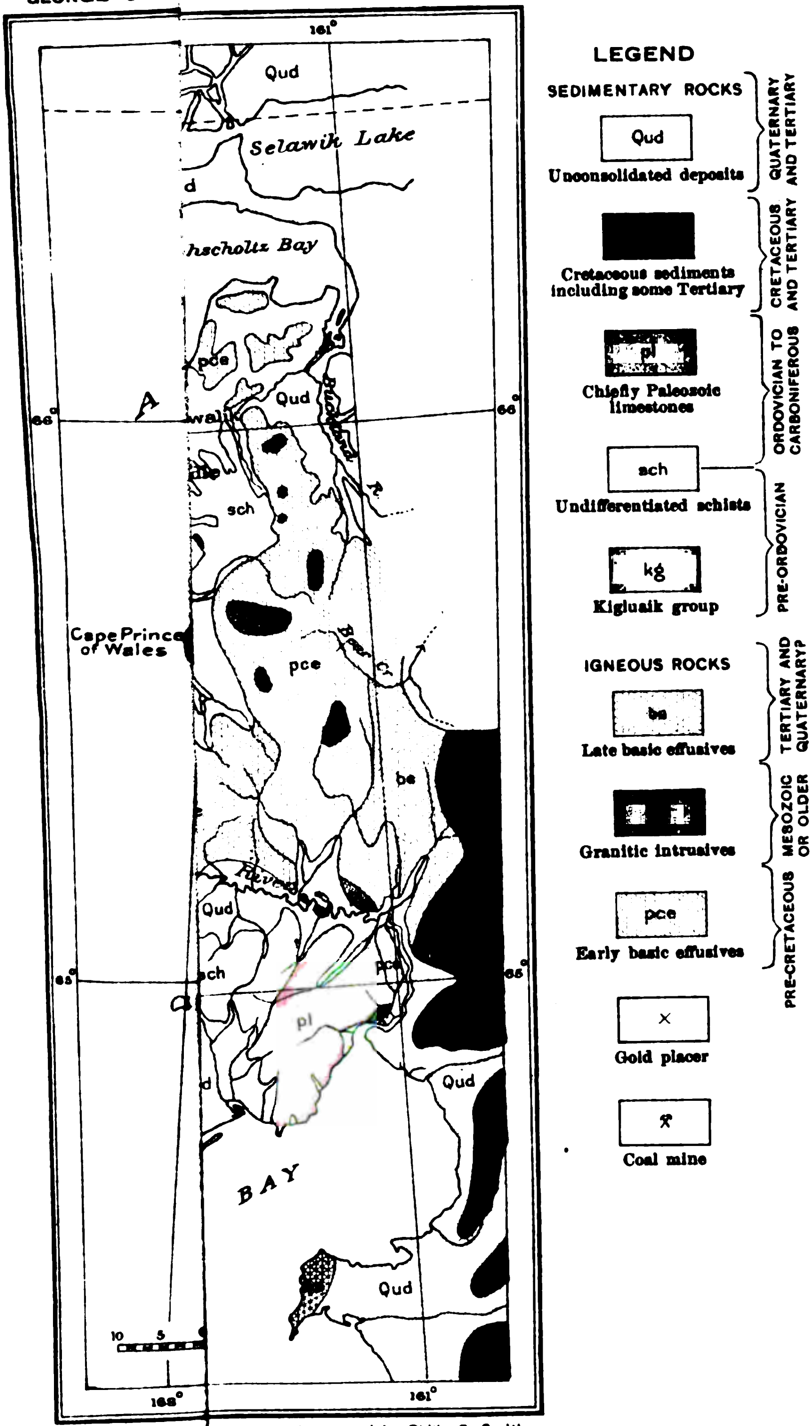
BULLETIN 533 PLATE V



ompiled and arranged by Philip S. Smith

A. VIEW NORTHWARD FROM NOME ACROSS THE TUNDRA.

Anvil Mountain in the distance, 4 miles away.

B. GLACIAL CIRQUE 1 MILE WEST OF PASS BETWEEN WINDY CREEK AND COBBLESTONE RIVER.

general distribution of these rocks. Undifferentiated schists and massive limestones occupy most of the peninsula, except a narrow belt extending westward from Koyuk River to Bering Sea. This belt is also made up of schist and limestone but includes many granitic intrusives. Sedimentary beds younger than any of these occur in the vicinity of Norton Bay. Unconsolidated gravel and sand deposits occupy wide areas of lowland and reach their greatest development on the Arctic coast, in the Imuruk Basin, and in a narrow belt along Bering Sea.

Igneous rocks are represented by the granitic intrusives already mentioned and by basic lava flows, some of which are of very recent age. The lava flows are not found in the western part of the peninsula and with a few minor exceptions do not appear west of Norton Bay in the southern part.

In the southern and western parts of the peninsula fossils have been collected that show all the great systems of the Paleozoic from Cambrian to Carboniferous to be represented. In the northeastern part schist and limestone of much the same character and probably of equivalent age are associated with younger coal-bearing rocks laid down in late Mesozoic or possibly Tertiary time. The consolidated sediments are therefore believed to range in age from early Palezoic to Mesozoic or Tertiary, but no Triassic or Jurassic rocks are known with certainty, and the Cretaceous sediments are practically restricted to the eastern part of the peninsula so far as present knowledge shows. In the region of Nome there are no consolidated sediments younger than Paleozoic.

The older sedimentary formations and possibly the younger also have been intruded by various igneous rocks, of which the most important are granites and diorites, or closely related types, and greenstones. The intruding rocks as well as those penetrated by them are generally more or less metamorphosed. Extrusive igneous rocks are represented by basic lavas in the northeastern part of the peninsula. The lower age limit of these lavas is uncertain and probably lies within the Mesozoic, but the upper limit is not earlier than Pleistocene or Recent, as the latest flows overlie gravels of Quaternary age.

Finally, to complete the geologic column, there must be added the unconsolidated surficial deposits, gravels, sands, and unsorted rock waste, of Pliocene, Pleistocene, and Recent age.

It must be admitted at the outset that in spite of all the work that has been done in Seward Peninsula the stratigraphy and geologic history of the area are very imperfectly understood, and the recent studies have only shown the problems to be more complicated than was supposed. The Paleozoic sediments, comprising much the greater part of the rocks of Seward Peninsula, were divided by the earlier geologists into three great groups called the Kigluaik, Kuzi-

trin, and Nome "series," the term "series" being used to include successions of associated formations distinct from one another but composed of individual members that could not be separated in reconnaissance work. These three divisions of the sedimentary rocks have been briefly described by Brooks,[1] who proposed them, as follows:

> The Kigluaik series is the oldest and is made up of a basal member consisting of heavy crystalline limestones, with mica schists, succeeded by a great thickness of mica schists and gneiss, and the entire succession is cut by large granite dikes. These rocks are overlain by the Kuzitrin formation, mostly graphitic slate and quartzite, with a thickness of probably 1,000 feet. The next horizon is the Nome series, whose basal member includes micaceous and calcareous schists, with some limestone, succeeded by several thousand feet of massive limestone called the Port Clarence limestone, containing Upper Silurian fossils.
>
> The Port Clarence limestone in places is overlain by schistose rocks, which constitute the upper member of the Nome series.

These three divisions have formed the basis of nearly all the geologic descriptions concerning Seward Peninsula since 1900, and two of them, the Kigluaik and Nome groups, are represented in the district to be considered here. They are now known to include sediments of widely different systems, limestones ranging in age from Cambrian to Carboniferous having been mapped as one formation. It is therefore evident that these names can be used only as they were intended to be used, as group names, and that they must finally be displaced altogether or greatly restricted in meaning.

Rocks of the Kigluaik group are found in the Kigluaik Mountains and their eastward extension, the Bendeleben Mountains. The Kigluaik-Bendeleben range marks an axis of anticlinal uplift, which brought the older rocks to the surface and forms one of the most prominent structural features of the peninsula. It extends from the coast of Bering Sea south of Port Clarence east to Koyuk River and the Darby Range north of Norton Bay.

Schists of the Kuzitrin formation, as previously defined by Brooks, are typically developed in the east or northeast end of the Kigluaik Mountains and along Kuzitrin River.

The Nome group, whose name is applied with less definite meaning than that of either the Kigluaik group or the Kuzitrin formation, is the most widely distributed of the three. It surrounds areas of the older group, includes small areas of infolded coal-bearing beds, and comprises most of the hard-rock formations of the peninsula. The schists and limestones of the Nome group have been subjected to distorting forces that have resulted in the production of two distinct sets of folds approximately perpendicular to each

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[1] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 217, 259.

other. The axis of one set of folds runs north and south. This folding was intense, and its results are seen in the southern and eastern parts of the peninsula but not in the northwestern part. The other set of folds is much more open and is most distinct in the vicinity of the Kigluaik and Bendeleben mountains, to whose axes the folds are parallel.

Coal-bearing sediments are found chiefly in the east end of the peninsula, although thin coal beds whose age has not been determined occur at one locality on Sinuk River, in the southwestern part. It appears probable that the coal and associated shales, sandstones, thin limestones, and conglomerate of the eastern part of Seward Peninsula are all of Cretaceous age, as there is now conclusive evidence that part of them are and the field relations favor such an assignment. These younger beds have been much folded, but they do not show such intense metamorphism as appears in the older rocks. They are known in only a few comparatively small areas on the peninsula, and these appear to be outliers of the great Cretaceous area extending east from the head of Norton Bay.

Surficial deposits occur throughout the peninsula and are locally of great commercial importance because of their content of placer gold.

STRATIGRAPHY OF NOME AND GRAND CENTRAL QUADRANGLES.

The oldest rocks within the area represented on the Nome and Grand Central maps are found near its northern boundary (Pl. IV, in pocket) and make up the greater part of the Kigluaik Mountains. They occupy about 45 square miles, or 8.5 per cent of the mapped area, and consist of biotite gneisses, coarsely crystalline limestone, biotite schist, and siliceous graphitic schist. They have a general dip to the south and are intruded by dikes and sills of granite, diorite, and diabase. The granite forms one area of considerable size. This series or group of rocks, omitting the graphitic siliceous schist but including limestones and gneiss not represented in the Grand Central quadrangle, was named Kigluaik by Brooks.[1]

Overlying the Kigluaik group and occupying nearly all the remainder of the area mapped (Pls. III and IV, in pocket) is another series of rocks consisting chiefly of chloritic and feldspathic schists and altered limestones with many greenstone intrusives. Beds of black graphitic schist or slate not distinguishable from those of the Kigluaik group occur in many places, and several small areas of granitic rocks, the largest being that of Cape Nome, are present. This series of sedimentary and igneous rocks, except the granites,

[1] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 27.

shows a more intense folding than is seen in the schists of the Kigluaik group, and its structure appears to be far more complicated. Brooks applied the name Nome to this group.

The Kigluaik and Nome groups comprise all the hard-rock formations of the Nome and Grand Central area, but the area contains widely distributed unconsolidated deposits. An extensive mantle of gravel, sand, and finely ground rock waste covers the lowland bordering Bering Sea, floors the stream valleys, and in the southern part of the region locally reaches well up on the hill slopes or covers the low parts of divides. These water-worn fragmental deposits are overlapped in most places by the more or less angular, unassorted débris that covers the upper slopes, in places even the tops, of all the hills, and that under the influence of frost and rain slowly works its way to lower levels. Less widely distributed but of local importance are the unconsolidated accumulations resulting from glaciation. A blanket of moss and other vegetation, overlying both the unassorted and the water-laid accumulations resulting from rock weathering, makes it impossible in nearly all places to see where the first begins or the other leaves off, and it is necessary to rely on a few scattered prospect holes for aid in drawing a boundary between them.

The outline of the stratigraphic succession just given is represented in the following table:

Quaternary (possibly including some Tertiary):
- Unconsolidated deposits—
  - Sands and gravels of marine and of fluvial origin; glacial deposits; mantle of unassorted débris due to weathering.

Paleozoic (probably middle Paleozoic):
- Nome group—
  - Schists with thin limestone beds and intruded greenstone sills.
  - Limestone with thin schist beds.
  - Schists with thin limestone beds and greenstones.

Early Paleozoic (possibly in part pre-Paleozoic):
- Kigluaik group—
  - Tigaraha schist (biotite schist, garnetiferous and staurolitic in places).
  - Limestone.
  - Gneiss.

The two lowest formations of the Kigluaik group are not present in the Grand Central quadrangle.

On the geologic maps (Pl. III and IV, in pocket) are represented the upper part of the Kigluaik group—the Tigaraha schist, the only formation of the Kigluaik group that is exposed in this area—and the Nome group, together with the larger areas of igneous rocks accompanying them and the gravel deposits.

The Tigaraha schist is distinguished from the schists of the Nome group by its lithologic character. Biotite is a characteristic feature of the Tigaraha schist and is in many places associated with staur-

olite. These minerals are not characteristic of the overlying rocks, and on the geologic maps the boundary between the top of the Tigaraha schist and the base of the Nome group is placed at the top of the staurolitic biotite schists. Thus an area of about 45 square miles occupied by the upper formation of the Kigluaik group is shown on the map. Within this area one principal granite mass occurs and there are smaller dikes and sills of granite or granitic rocks in a number of places, more especially south of Thompson Creek.

Much the greater part of the mapped area is occupied by the Nome group. Two principal types of rock are represented—schists and the most important limestones. Greenstone areas also are mapped in several places, but no attempt has been made nor does it appear possible to differentiate the greenstone schist of igneous origin from that of sedimentary origin. In outlining the limestone areas it was not found desirable to indicate many of the thin schist beds occurring in the limestone, because the exposures in most places are too poor to allow it to be done with a reasonable degree of accuracy. Poor exposures also have made it impossible to correlate many of the limestone outcrops, and as no fossils were found in any of the limestones, and there are no other distinctive features that permit individual beds to be recognized over any considerable area, the detailed structure of the Nome group is not fully understood. The surprising irregularity of the limestone areas is due in part to faulting, in part to variation in thickness of the beds, and possibly (see p. 29) in part to unconformities within the Nome group, although no definite evidence of this possibility was obtained. Many thin limestones interbedded with the schists as well as calcareous phases of the schist are not represented. A number of granite areas, one near Copper Creek, several east of Mount Distin, and a large one at Cape Nome appear within the Nome group and are outlined on the map. The boundary of the granite mass at Cape Nome, however, is only approximate, as the contact is nowhere exposed.

In representing the gravels it is necessary, owing to the small scale of the map, to leave the color off most of the smaller streams, hence in examining the areas of the deposits it should be remembered that gravels are present on all the creeks, at least in their lower portions. Only surficial deposits that have undergone sorting by water or have resulted from glacial action are shown. Undoubtedly there are on hill slopes and in some of the saddles areas of gravel that are not represented on the map. Inaccuracies in the boundaries of gravel areas will also be found, but these are inevitable in a region where so much of the surface is covered with moss or with rock waste from the upper hill slopes.

KIGLUAIK GROUP.

LOWER FORMATIONS.

The Kigluaik group, as it is seen in the region of Mount Osborn, comprises three principal formations—a basal gneiss, an overlying heavily bedded limestone, and an upper formation consisting of a great thickness of schists and a few thin limestone beds.

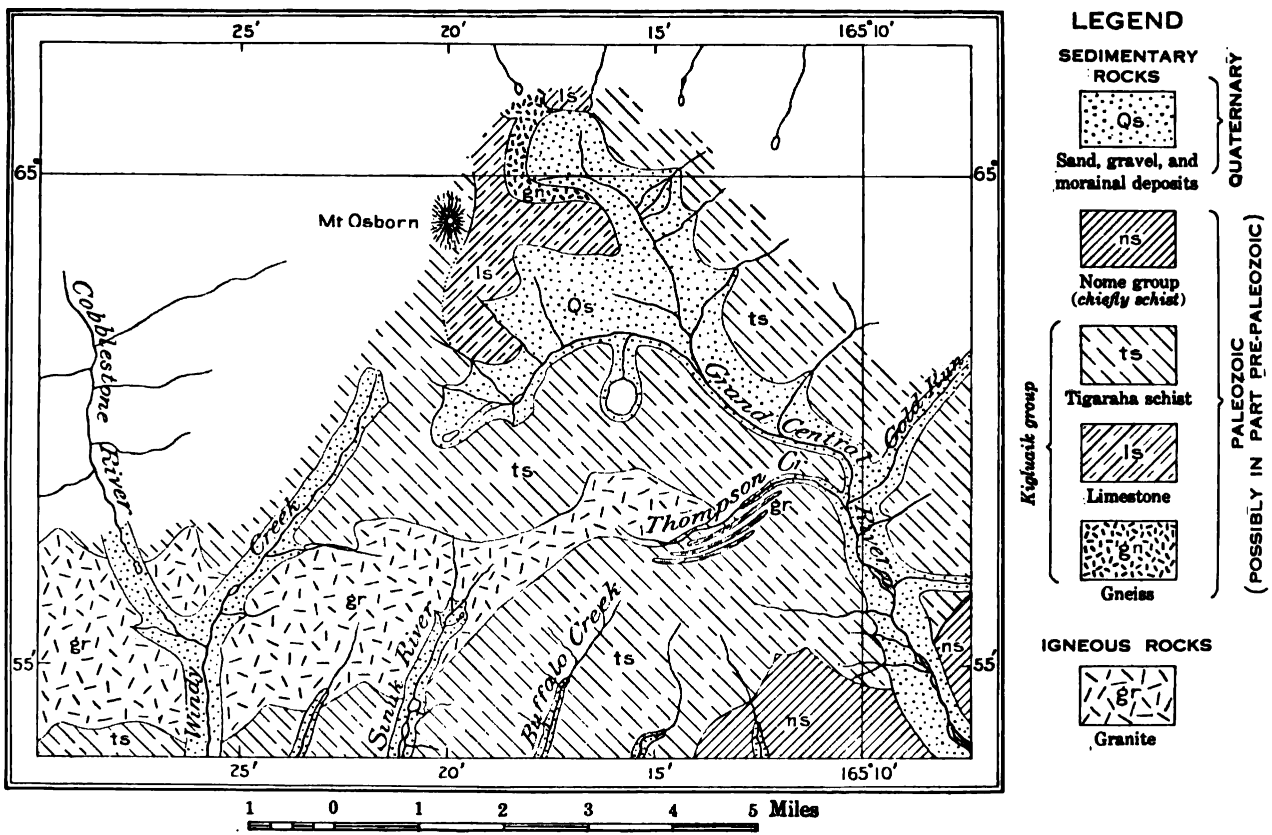
The lowest formation is not exposed within the area represented on the Grand Central map. It is found at the base of Mount Osborn and consists of a biotite gneiss cut by many intrusive masses. (See Pl. VII.) These two rocks are mingled in a most intimate way. The light-colored granitic portions intensify this appearance, as they are drawn out and folded and show a well-developed flow structure. The gneiss is a dark coarse-grained rock containing a large amount of biotite and forms more than half the vertical section of Mount Osborn. (See Pl. XI, p. 62.)

The coarsely crystalline limestone overlying the gneiss does not appear at the surface in the Grand Central area. It has a thickness of 800 to 1,000 feet and is well seen on the east side of Mount Osborn, where its complete section is exposed (Pl. XI). In the central mountain mass it lies horizontal, but on the south and east, possibly on the west and north also, it dips under the schist.

The limestone gives rise to some of the most striking topographic features of the region. It forms the uppermost precipitous slopes of Mount Osborn, on whose top, however, a small mass of schist still remains, and it caps the lower summits on the north, where the white cliffs stand out prominently. All exposures are much weathered, the crumbling débris lying in small talus slopes at the base of the ledges. Although this limestone has been subjected to alteration in various ways and is entirely recrystallized, it does not show secondary minerals like those found in some of the thinner limestone beds of the Kigluaik group.

TIGARAHA SCHIST.

Overlying the limestone of Mount Osborn is a great thickness, at least several thousand feet, of brown-weathering biotite schist, to which the name Tigaraha is applied. The type locality includes a sharp peak near the head of Buffalo Creek, which is here given the name Tigaraha Mountain, ti-ga-rah′-a being the Eskimo word for pointed. As used in this paper the term Tigaraha schist denotes all that part of the Kigluaik group between the top of the limestone of Mount Osborn and the base of the Nome group. Between Mount Osborn and the upper valleys of Sinuk and Nome rivers the schist dips uniformly to the south at angles less than 35° in most places



GEOLOGIC SKETCH MAP OF REGION AT HEADS OF GRAND CENTRAL RIVER AND WINDY CREEK.

where observations were made. The south wall of the west branch of Grand Central River, which is made up entirely of the Tigaraha schist, exposes at least 2,500 feet of the formation, but does not include its upper and probably greater part.

The Tigaraha schist as defined shows variety in the character of the sediments from which it was produced, but the presence of biotite is a constant feature and was used by the earlier workers, as it has been in this report, as a means of distinguishing the schists of the Kigluaik Mountains from those of the Nome group. Collier,[1] in describing the schists of the Kigluaik group, says: "The schists which comprise the greater part of this group are generally dark gray in color and consist essentially of quartz and biotite, with various accessory minerals in the different beds, such as graphite, pyrite, magnetite, garnet, staurolite, hornblende, augite, orthoclase, plagioclase, etc."

The schist is for the most part fine grained and has a rather smooth cleavage. Biotite is the conspicuous mineral. Large red garnets are not uncommon. Locally many small flakes of graphite are present, and on hasty examination might readily be confused with the mica. The brown color by which the outcrops may be distinguished at considerable distances is due to a small amount of iron oxide resulting from the weathering of iron-bearing minerals in the schist. Thin dikes and sills of coarse pegmatitic granite are numerous, and larger masses of finer-grained granite have been intruded.

Above the brown-weathering lower part of the schist lies more biotite schist, which is highly siliceous in most places and may possibly represent altered sandstones or quartzites. Still higher, forming the upper part of the group, are beds of staurolite-biotite schist and black siliceous graphitic beds. Staurolite schist was found in the upper part of the Kigluaik group wherever the top of the group was observed. The black graphitic beds are irregular in their areal distribution and exceedingly variable in thickness, being far more prominent east of Buffalo Creek than west of it. It should be said, however, that west of Buffalo Creek they may be covered by the gravel deposits of Sinuk River. The black graphitic schist is a hard siliceous rock with a platy cleavage and is entirely distinct from the graphite-bearing schist overlying the heavy limestone. In the former the carbonaceous matter is present as a fine dust throughout the rock, whereas in the latter graphite occurs as well-defined scales or flakes.

These black beds were considered by the earlier workers to be entirely distinct from the Kigluaik group and were believed to be

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 66.

part of the Kuzitrin formation. It is difficult to determine exactly the relation between the two, but in the Grand Central region there can be no doubt that in some places the thinner beds are entirely conformable with the biotitic schist with which they are interbedded.

From evidence obtained along Kuzitrin River northeast of the Kigluaik Mountains, where the black beds are best developed, Brooks considered their probable relation with both the underlying biotite schists and the overlying Nome group to be one of unconformity, but states that the evidence is not conclusive.[1]

Although the name Kuzitrin has been applied to the black carbonaceous schists on the south flank of the Kigluaik Mountains east and west of Nome River, the separation is not made here, because the black schists occur interstratified with biotite and staurolite schists that have been included in the Kigluaik group. At the same time it should be kept in mind that, as previously stated, these black beds are not distinguishable lithologically from the black carbonaceous schists of the Nome group. The relative age of the beds is known only by their stratigraphic position, for no organic remains have been discovered in any of the rocks described. Moreover, there is a doubt whether they can be correctly correlated with the black schists or slates of the type locality on Kuzitrin River. There seems, therefore, to be no good reason in this particular region for separating schists that differ no more than these do in lithologic character and that follow one another in conformable succession, unless the separation can be made on evidence afforded by fossils. Consequently the siliceous beds with their staurolitic and intercalated carbonaceous members are regarded as forming the upper part of the Tigaraha schist.

Thin limestones appear here and there in the Tigaraha schist, but are not so numerous as in the schists of the Nome group, to be described later. The limestone beds are invariably much altered. They have become coarse, crumbling marbles and in places contain secondary minerals, such as spinel, malacolite, and a light-brown mica. These minerals were found in limestones that have been highly folded and are associated with granitic intrusions. In the upper part of the Grand Central River valley there are bowlders which consist of a highly altered malacolite-bearing limestone containing many rounded pebbles of various dark eruptives, but the rock from which these bowlders were derived was not found in place. The limestone beds in the upper part of the Kigluaik group are less altered than those in the lower part, and the secondary minerals mentioned above were not seen.

[1] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 29.

AGE.

The basal beds of the Kigluaik group are believed to be among the oldest strata exposed on Seward Peninsula and possibly in Alaska, although the rocks themselves contain no fossils to support this belief, and it is not now susceptible of proof. The evidence in its favor is derived from the stratigraphy, from the character of the rocks, and from comparison with other districts.

The oldest known fossiliferous sediments of Seward Peninsula are exposed in the York Mountains, about 60 miles northwest of the head of Nome River. Upper Cambrian fossils were found there by Kindle in limestone that had been regarded as part of the Port Clarence limestone. There is no proof that the Cambrian limestone of the York Mountains is equivalent to the massive limestone at the base of the Kigluaik group, but there can be little doubt that the latter is older than part of the limestone that has been called Port Clarence. The limestone of Mount Osborn rests on gneiss and is itself highly metamorphosed. Moreover, it underlies the Tigaraha schist, and the best available evidence favors the view that it is older than the schists and limestones of the Nome group south of the Kigluaik Mountains. A large part of the schists and limestones of the Nome group are considered to be of Silurian and Ordovician age, although, as stated, Cambrian and Carboniferous limestones have also been included in it.[1] The age of the Nome group will be considered more fully later, but evidently there is ground for considering the Kigluaik group as early Paleozoic rather than late Paleozoic, and it may be Upper Cambrian or earlier, possibly even in part pre-Paleozoic.

INTRUSIVES ASSOCIATED WITH THE KIGLUAIK GROUP.

All the formations of the Kigluaik group are cut by intrusives, the most common of which is granite. These intrusive rocks, however, are far more abundant in the lower part of the group than in the upper part. Besides the granite intrusives, dikes and sills of diorite, diabase, and pegmatite are present.

GRANITE.

The granite is a normal biotite granite belonging to two or more periods of intrusion, as is shown by intersecting dikes and possibly by differences of alteration. Its color is light gray, and it varies greatly in the amount of alteration it has undergone. In some places it is massive, with no marked cleavage, but in others it is a coarse

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 62.

gneiss or schist. The gneissoid or schistose phases show the development of a considerable amount of biotite. Although they may possibly represent older intrusions that now form part of a larger granite complex, it is probable that, in part at least, they belong in zones where pressure on the whole mass has found relief in the development of the secondary structure.

Some of the finest scenery and most rugged topography of the Kigluaik Mountains is due in part to the presence of these intrusions of granite. The lofty southern walls of several valleys are formed by it, and many of the gentler slopes are entirely covered with the massive blocks pried off by the winter's ice. Perpendicular joint planes have permitted frost to carve the rock into all sorts of fantastic shapes, and the spires and pinnacles rising from the steep ridges (Pl. VIII, *A*) have given this range the name by which it is commonly known—the Sawtooth Mountains.

The largest granite mass of the region extends from the western limit of the Grand Central quadrangle eastward across Windy Creek and Sinuk River to the head of Thompson Creek, occupying a wedge-shaped area with its narrow end toward the east. It is intruded along the bedding planes, underlying the schists on the south and overlying those on the north. At the head of Thompson Creek it loses its individual character and splits up into many sills (Pl. VIII, *B*), which are well shown on the steep slope south of the stream. The separate sills there continue for long distances with only little difference in thickness or character. In places the large granite mass is cut by black diabase dikes and more rarely by dikes of diorite.

In the Kigluaik group small dikes and sills are most numerous near the main intrusive masses and show themselves to be of different ages by the manner in which they intersect one another and possibly by their different degrees of metamorphism. On one of the tributaries of Cobblestone River, north of Windy Creek, a banded gneiss is cut by a dike of fine-grained light-gray granite. This in turn is crossed by a second gray granite, and all three are cut by black diabase dikes.

DIORITE.

Diorite is not a common rock in the Kigluaik Mountains. It was observed in only a few places, where it occurs as small dikes associated with the granite. Dikes of diorite cut the granite in the vicinity of Windy Creek and are conspicuous because of their dark color. These dikes are fine-grained rocks with a pepper and salt appearance, produced by the little grains of feldspar and black hornblende. They are more or less sheared wherever they were seen and have a good cleavage. When examined under the microscope sections of the dike rock are found to consist almost entirely of horn-

A. CHARACTERISTIC RUGGED RIDGE IN THE KIGLUAIK MOUNTAINS.

View to the northeast from saddle at head of East Fork of Grand Central River.

B. GRANITE SILLS IN THE SOUTHWARD-DIPPING BIOTITE SCHIST OF THOMPSON CREEK.

blende and plagioclase feldspar, with magnetite, apatite, and zircon as accessory minerals. Some sections show biotite and titanite also. In spite of the well-developed cleavage, the rock is remarkably fresh.

DIABASE.

Dikes of diabase are more numerous than dikes of diorite in the portion of the Kigluaik Mountains included in the Grand Central quadrangle. In the lower part of the Kigluaik group, in the vicinity of Mount Osborn, they are abundant. They appear to be the most recent and least altered of all the intrusive rocks of the region. All the dikes seen were small, most of them not more than 2 or 3 feet thick. The microscope shows them to be typical diabases having a felty groundmass of lath-shaped feldspar with pyroxene crystals between. Magnetite and a little biotite are present. A slight alteration is usually seen, and in some sections the alteration is considerable but not enough to hide the original characters of the rock.

PEGMATITE.

Pegmatite dikes are numerous in the Tigaraha schist between Sinuk River and the granite area on the north, particularly in the little area of schist west of Windy Creek. None of them were traced into the granite mass, but it is believed that their origin is directly connected with the granite intrusion. A small dike about a mile west of the mouth of North Star Creek is typical of these pegmatites and attracts attention because of the beauty of some of its well-crystallized minerals. It is light gray in color and consists principally of gray quartz and bluish-gray feldspar that are in places intergrown in such a way as to produce the structure of graphic granite. The associated minerals seen in the hand specimen are brown and white micas, tourmaline, garnet, and beryl. Feldspar crystals up to 1 inch or 1¼ inches in diameter are plentiful. Black tourmalines 2 or 3 inches long and up to half an inch in diameter are probably the most conspicuous of the minerals. They are arranged radially in places but near the edge of the dike assume positions perpendicular to the walls. Tourmaline and white mica are most abundant near the contacts with the schist. Red garnets are exceedingly abundant and range in size from those almost too small to see without the microscope to those one-quarter inch in diameter. Their crystal forms are finely developed. Some crystals of beryl are seen.

In the schists about the head of Windy Creek coarse pegmatites carrying graphite are present as sills and dikes, but they resemble coarse granite and do not present the interesting features of the dike just described. The occurrence of such dikes in the vicinity of Windy Creek and the presence of stream tin on Goldbottom Creek

only a few miles to the south suggest the possibility that some of the pegmatites may be found to carry tin.

AGE.

It has been shown previously that the intrusives in the Kigluaik group were injected at several different periods. This is well illustrated by the occurrence on Cobblestone River, where the gneisses are cut by three distinct intrusions, and by that on Windy Creek, where diorite dikes cut the massive granite. Granite dikes cut the Nome schists also, and very extensive intrusions of diabase in the form of sills and dikes are widely distributed through the Nome group. All these igneous rocks are more or less metamorphosed and are therefore distinctly older than the recent lavas of northeastern Seward Peninsula. No evidence to show that the granitic intrusives of the Kigluaik group are older than those of Nome group has yet been found, but it is believed that the pegmatite dikes of the Kigluaik Mountains are associated in origin with the granitic intrusives. The pegmatite dikes show little alteration and are therefore assigned to one of the later periods of intrusion. It is recognized, however, that the degree of metamorphism may be an unsafe guide in determining the relative age of rocks in this region. Smith and Eakin[1] have shown that the massive Cretaceous conglomerate east of the Darby Range contains granitic bowlders and pebbles derived from the Darby and Bendeleben mountains, and further that there are minor granitic intrusions in the Cretaceous sediments. Without much doubt the principal periods of intrusion for the granites and related granular rocks are pre-Cretaceous. Possibly part of them may belong to the period of intrusion that occurred in late Jurassic time and is well represented in many other parts of Alaska, such as the south coast region. Others are probably very much older.

For lack of definite evidence as to the age of the inclosing rocks, it is not possible now to do much more than determine the relative age of such intrusives as afford favorable conditions for observation, like those in the localities noted.

NOME GROUP.

The Nome group within the area under discussion consists mainly of schist but includes limestone, which is present in most of the area and is important in several parts of it. Calcareous schist or impure schistose limestone is locally well represented and is in many places of such character as to cause doubt whether it should be mapped as limestone or as schist.

[1] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region: Bull. U. S. Geol. Survey No. 449, 1911, pp. 55 et seq.

SCHIST.

The different kinds of schist may be broadly classified as chloritic schist, feldspathic schist, and siliceous graphitic schist, but these all present numerous variations.

Chloritic schist is the most common kind. In fact, chlorite is rarely absent in any of the schists except the siliceous graphitic varieties, although the amount is in places very small and may not be sufficient to give any marked greenish tinge to the rock. In such less chloritic phases of the schist, quartz is more prominent and with the mica gives a gray color to the fresh specimens. Contrasted with such types are those in which chlorite is the most prominent mineral, and the rock takes on a characteristic green color. Such schist in places grades into the least feldspathic of the feldspar-bearing schist, which carries the albite crystals in amounts not readily seen without the microscope.

The feldspathic schist is so called from the presence of small albite crystals, most of which are not over an eighth of an inch in greatest dimension, though some reach diameters of one-quarter or three-eighths of an inch. The feldspar gives a peculiar speckled appearance to the rock and is best seen on a surface cutting across the cleavage. On cleavage surfaces the small white crystals may be entirely hidden by scales of mica or chlorite. Chlorite is present throughout, and usually more or less quartz may be recognized. The schist is green or greenish gray because of the chlorite constituent, but in certain places the color may be due in part to a considerable content of epidote and hornblende.

A part of the feldspar-bearing schist is derived by metamorphosis from rocks of sedimentary origin and another part results from the alteration of igneous rocks described on page 32. Proof of the sedimentary origin of some of the feldspathic schist is afforded chiefly by its field relation with the associated schist or limestone. Exposures of thin-bedded feldspathic schist and limestone are found at a number of localities and are of such a character as almost to preclude the possibility of the schist having any other than a sedimentary origin. A 6-foot ledge of this kind on the south side of David Creek was found to be made up of alternate beds of feldspathic schist and yellow-weathering limestone, none of which were over 2 inches thick and which averaged probably not over 1 inch.

It is possible that feldspathic schists of this kind have been derived either from sediments resulting from the rapid breaking down of igneous rocks and the accumulation of the waste material in arkose or graywacke beds, or from beds of tuffaceous material formed at times of volcanic outbursts and outpourings of lavas such as are abundant in parts of Seward Peninsula. This theory of origin is

suggested as a reasonable explanation of the similarity between feldspathic schists believed to be altered sediments and those believed to be altered igneous rocks. The proof of such an origin for the schists under discussion is lacking, however, for the rocks are now too greatly changed to give reliable testimony as to their original condition. The outcrop on David Creek is believed to furnish evidence of rapid and repeated changes of conditions of sedimentation, causing the deposition of calcareous material to be frequently interrupted by that of argillaceous material whose chemical composition was such that on being metamorphosed it was capable of producing feldspathic schists similar in appearance to those of igneous origin. The second kind of feldspathic schist will be considered in connection with the eruptive rocks associated with the group.

The siliceous graphitic schist is black or dark gray. Quartz is its chief constituent, and a fresh surface is commonly covered with a fine black dust which soils the hands. The rock is hard, weathering into angular platy fragments that ring under the feet like cinders when the shattered outcrops are crossed. Many exposures are recognizable at considerable distances by their color, but may be confused with the black lichen-covered débris of some of the more siliceous chloritic schist. As far as external appearance is concerned, the rock is exactly like much of the siliceous graphitic schist of the Kigluaik group, but none of it shows any biotite on the weathered surface.

No definite constant relation was made out between the black schist and the other schists or the limestones. The black schist occurs irregularly in many parts of the region, the largest area of it being on the ridge between Anvil Creek and Snake River. The south end of this ridge is made up of the black schist, which continues along the top of the ridge about three-quarters of a mile. Another large area is at the north end of the top of the hill between Goldbottom Creek and North Fork. Still another is at the top of the ridge between Charley Creek and Stewart River.

The black schist beds of the Nome group are in most places thin, rarely reaching a thickness as great as 50 feet. On the ridge between Charley and Silver Creeks beds of black schist from 1 foot to 2 or 3 feet thick are interstratified with chloritic schist. At this locality the amount of graphitic material appears to vary along the strike of the beds, so that in places the rock becomes a gray quartzite. The same variation in the proportions of quartz and graphitic material was observed at other places.

LIMESTONE.

Limestone beds are interstratified with schist in all parts of the Nome group. They are for the most part light gray or bluish gray

in color, but in places they are dark gray owing to the presence of carbonaceous matter. All these limestones are metamorphosed in some degree, many being entirely recrystallized. A careful examination of beds that at first glance appear to be little disturbed may show that they have been intensely folded and that the overturned portions have been compressed so that the limbs of the folds lie parallel with the bedding. Folds of this kind occur at short intervals. (See fig. 2.) Large exposures show that the limestones are cut by many joint planes and by small faults.

Heavy limestone beds form prominent topographic features in many localities. The cliffs and ledges or the rounded hills strewn with white limestone fragments are recognizable at considerable distances and easily lead to the belief that the rock covers far greater areas than it does. Irregularity in thickness characterizes most of these beds. Heavy strata thin out abruptly or disappear altogether. Some of these changes are due to faulting, but others have resulted

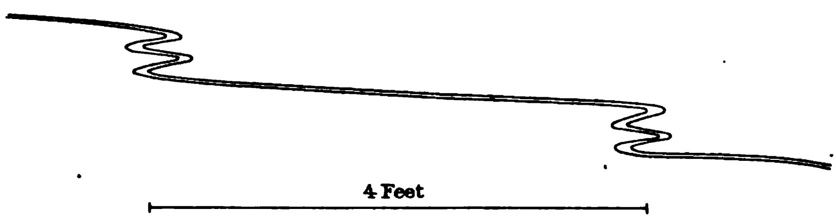


FIGURE 2.—Folded beds in thick horizontal limestone stratum.

from a rapid decrease in thickness, some possibly from a change in sediment along the strike, although no unmistakable example of such a change was seen. Unconformities within the Nome group might give rise to such an irregularity also, and this explanation was kept in mind during the field work, but no definite proof of it was obtained. Some evidence was collected, however, which indicates that unconformities may exist. Another explanation of this variation which seems to apply in some places is that the beds have been either thickened or compressed by the pressure and folding that they have undergone. An overturned fold pressed tightly together could give rise to the condition described.

Many limestone beds, too small or too poorly exposed to be separately mapped, occur throughout the Nome group. These range in thickness from a few inches to possibly 50 feet or more. The most extensive limestone area shown on the map includes Mount Distin and vicinity. Mount Distin is a mass of interbedded limestone and chloritic schist cut by greenstone dikes, limestone being by far the most abundant member. It is a synclinal mountain with the strata dipping in on all sides. The base of the mountain, as is best shown on its southern slope, is made up of alternating beds of limestone and

schist, capped by not less than 800 feet of heavily bedded limestone, in which are a few brown-weathering impure beds. These interbedded limestone and schist strata make up the area included by Stewart River, Goldbottom Creek, and Nome River, but they are folded and faulted so that their areal distribution is extremely complicated.

These rocks are probably to be correlated with those in the area extending southwest from Salmon Lake to Nome River, also with those east of Nome River below Hobson Creek, but whether they correspond with the limestone forming the south front of Anvil and Newton peaks or with those at the head of Osborn Creek or on Fox Creek is questionable. The limestone forming the north front of the hill south of Salmon Lake is not less than 800 feet thick, but toward the southwest interbedded schists appear and faults are so numerous that the structure and thickness are uncertain. It is evident, however, that the limestone has no such thickness as is shown in Mount Distin. Between Sampson and Basin creeks the upper part of the limestone is a heavy bluish-gray bed at least 600 feet thick. It overlies interbedded schist and limestone which also have a thickness of not less than 600 feet. It is much faulted and toward the south disappears altogether.

Collier[1] has correlated the limestone of Mount Distin and the limestone south of Salmon Lake with the Port Clarence limestone of Cambrian and Ordovician age, which is typically developed in the northwestern part of Seward Peninsula, and was named from its occurrence near Port Clarence. This correlation was made on stratigraphic and lithologic grounds and not on fossil evidence or structural continuity. No new evidence on this question was discovered during the field work of 1905 and 1906, but in view of the fact that Cambrian and Carboniferous limestones have been mapped as part of the Port Clarence such a correlation can now mean no more than that the limestone of Mount Distin corresponds to some part of the Port Clarence limestone.

The southern faces of Anvil Peak and Newton Peak are formed by a limestone that extends from Anvil Creek to Nome River. It dips north under the schists that make up the greater mass of these hills, but stops abruptly at Anvil Creek. Drill holes along Nome River from Laurada Creek to Tripple Creek show limestone bedrock, which probably is part of its eastward continuation. It is folded and faulted, and its base in most places is covered by débris from the hill slopes and by gravels of the Nome tundra, so that its thickness is uncertain, though it can hardly be less than 400 feet.

[1] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 15; The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 62.

Another limestone mass of considerable size lies between New Eldorado Creek and Flambeau River, and its cliffs form a prominent topographic feature of the region. It overlies and is overlain by schist, thus forming an irregular zone around the central schist mass. The overlying schist is in part an altered intrusive, a fact which may account for the apparent great variation in the thickness of the limestone.

AGE.

In discussing the age of the Nome group it is necessary to make reference to previous geologic work in other parts of the peninsula that has had to do with the same problem. The Nome group has been held to consist essentially of three formations, two of schist, separated by the third, a massive limestone formation called the Port Clarence limestone, from its type locality north of Port Clarence. This limestone occupies extensive areas in the northwestern part of the peninsula and from fossil evidence was considered by Collier[1] to be of Ordovician and Silurian age. It overlies a succession of arenaceous slates that are exposed a short distance northwest of Cape York,[2] but its relation to the graphitic, chloritic, and calcareous schists north of Grantley Harbor is obscure, although it has been supposed to overlie them also. These last-named schists, as mapped by Collier, underlie the limestone of Baldy Mountain north of Kuzitrin River, which he considered as belonging to the Port Clarence and from which Carboniferous or Devonian fossils are reported by Kindle.[3]

Kindle also found Upper Cambrian fossils in the Port Clarence limestone of the York Mountains. In brief, the rocks that have been mapped as Port Clarence limestone are not a single formation, but are composed of various limestones ranging in age from Cambrian to Carboniferous. They can not be correlated as a whole with the limestone of Mount Distin and the south side of Salmon Lake valley. Probably the limestone of Mount Distin is equivalent to some part of the Port Clarence limestone and is of Paleozoic age, but no evidence has yet been obtained for any more definite correlation. We are thus at a loss for satisfactory evidence as to the age of the other formations of the Nome group, as correlation of the schists is even more difficult and uncertain than correlation of the limestones. It seems probable that a middle Paleozoic age for the limestones and

[1] Collier, A. J., The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, Pl. XI, in pocket.

[2] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: Bull. U. S. Geol. Survey No. 358, 1908, p. 13.

[3] Kindle, E. M., The faunal succession in the Port Clarence limestone: Am. Jour. Sci., 4th ser., vol. 32, 1911, p. 349.

schists of the Nome group may some day be established, but it can not be done with the evidence now at hand.

IGNEOUS ROCKS ASSOCIATED WITH THE NOME GROUP.

The igneous rocks associated with the Nome group are of two general classes—greenstones or altered basic intrusives and granitic rocks. Greenstones are distributed irregularly through the entire area under consideration. The granitic rocks, on the other hand, are not abundant and are found in notable quantity in only one locality.

GREENSTONE.

The rocks called greenstone are all more or less altered intrusives occurring as dikes and sills that cut the limestone and schist formations of the Nome group and the granite of Cape Nome. No igneous rocks of exactly the same character were seen in the Kigluaik group. The dark basic dikes found there are all of diabasic or dioritic varieties; and although the greenstones are probably related to the diabasic dikes they are in a measure distinct.

The less schistose greenstones are heavy dark-green rocks of fine grain, in which the most conspicuous minerals are red garnet and pyrite or the iron oxide resulting from its decomposition. The bright cleavage faces of small hornblende crystals and the lighter green of the chlorite may also be distinguished. In some of the greenstone, however, garnet and pyrite are present only in small quantity and may not appear in a hand specimen. The most typical and least schistose greenstone, such as is found near Osborn Creek, when examined with the microscope shows garnet, green and blue hornblende (glaucophane), chlorite, epidote, and titanite surrounded by albite, which contains many small inclusions and forms a sort of groundmass. Magnetite or ilmenite, pyrite, titanite, rutile, quartz, and calcite are found in some of it. The rock of this locality is an eclogite and where most metamorphosed has become a feldspathic schist. It is extensively exposed in the southern two of the three rounded hills between Osborn and Buster creeks, where it is associated with limestone beds and with chloritic and feldspathic schist. Its relation to these rocks is not clear, but the greenstone probably occurs in them as large sills or dikes. The outcrops are few, and little débris other than that of the greenstone is seen on these hills.

Greenstone intrusives are common east of Nome River, but are less prevalent west of it. They are found in the vicinity of Newton Peak and Mount Distin and at a few other places as dikes cutting the limestone. As a rule the greenstones do not appear as ledges in place, but as heaps of blocks or smaller débris strewn over the hill slopes or tops.

The degree of metamorphism varies greatly, but greenstone is found which has not been highly altered. Where it is inclosed in limestone it seems to have suffered less from pressure and is less schistose than where it cuts the other rocks. Even the hard massive blocks, which appear to have undergone little metamorphism, are seen, when studied microscopically, to contain a large proportion of secondary minerals.

GRANITE.

The largest granite area is found at Cape Nome. It includes gray granite, some of it slightly yellow from weathering, and gray gneiss, apparently derived from the granite by metamorphosis. The seemingly homogeneous granite when looked at in a large way is seen to have a banded structure like the gneisses. Both granite and gneiss are intruded by greenstone and by a coarse dark-gray porphyritic rock containing feldspar crystals, many of which are 1 to 1½ inches in diameter. The porphyritic intrusion in turn is cut by granite.

The granite is a fine-grained biotite rock more or less metamorphosed. Allanite is commonly present. Epidote is seen in many of the thin sections, also microcline and titanite or leucoxene. The common secondary minerals are chlorite and albite. The degree of alteration expressed by the development of schistosity varies in different parts of the mass and is greatest near the boundaries, especially toward the north, where the granite either has become a feldspathic schist or grades into it. The porphyritic phase is a darker gray than most of the other granite, but its most notable feature is its abundant content of large crystals of orthoclase feldspar. Quartz, orthoclase, microcline, albite, epidote, and biotite are the principal minerals seen with the microscope. Allanite is present in much of it. The large feldspar crystals are filled with minute mineral inclusions, chiefly quartz.

Only part of the granite area, about 3¾ square miles, is included in the Nome quadrangle, and the greater portion may lie east of it. The boundaries, however, are indefinite, for the contact is nowhere seen, and outcrops, except on the seaward face of Cape Nome, are few. It is not possible with the data available to determine whether the granite of Cape Nome was intruded into the Nome group or whether the rocks of the Nome group were laid down upon it. Furthermore, there is no means of telling what age relation exists between the granite of Cape Nome and the granite intrusions of the Kigluaik Mountains. Like the latter, it is the product of several intrusions, but whether the intrusions took place at widely different times has not been determined. The greater alteration of the granite

of Cape Nome and the presence in it of allanite, a mineral not seen in the northern granites, may be considered as indicating greater age and a different source, but these differences seem to be hardly sufficient to warrant the statement that the two granites are entirely unrelated.

Two or three small areas of much-altered granite are found within the Nome group, the most notable lying northeast of Mount Distin in the vicinity of Lost Creek and on the north slope of the hill west of Copper Creek. They are most probably associated with the granite intrusives of the Kigluaik group.

AGE.

Little more can be said about the age of the intrusives in the Nome group than has been stated in considering the intrusives in the Kigluaik group. They belong to several widely separated periods, possibly ranging from the Paleozoic into the Mesozoic.

A large part of the greenstone intrusives, both sills and dikes, are extensively metamorphosed. Most of them are entirely recrystallized and show the secondary structure of the inclosing schists. A smaller part, represented chiefly by dikes in limestone and in schist, have undergone severe alteration, but do not show the secondary structure, such as cleavage or schistosity, of the inclosing rock. Good evidence for a number of distinct times of intrusion is shown in the granite area of Cape Nome, where the oldest granite and the gneiss, which may themselves be of different ages, are cut by dikes of greenstone and of porphyry, and the porphyry in turn is cut by granite. Such relations show the complicated character of the history of the intrusions and indicate the relative age of the intrusive rocks. They do not, however, reveal anything as to the time of intrusion, and such information must be gained from the inclosing rock and from the relations between it and the intrusives. Probably the periods of intrusion extended into post-Cretaceous time, but no lower age limit can be given, because the age of the sediments composing the Nome group is unknown further than that they were probably laid down in Paleozoic time.

VEINS.

Deformation and rupture of the rocks, especially those of the Nome group, have given opportunity for the circulation of mineral-bearing solutions and the deposition of veins of quartz and calcite. Quartz occurs principally as lenses and stringers in the schist, but also as well-defined veins cutting the schist. The small quartz deposits in the schist and perhaps some of the larger veins also are believed to have been introduced during the time in which the principal deforma-

tion of the Nome group took place, for many of them are found to be folded with the schist and to have suffered alteration with it.

Veins of white quartz of considerable thickness—10, 12, or even 20 feet—occur, but none yet observed have been traced for more than short distances. It is suggested that they may be connected genetically with the pegmatite dikes found in the Kigluaik Mountains, but of this there is no definite proof, and in fact their small horizontal and vertical extent would seem to oppose this idea. They are believed to be younger than the small veins and lenses just mentioned but have been subjected to the later movements that affected the schists in which they occur. In several localities small prospect holes or short tunnels driven in the large quartz masses show the quartz to be much broken and faulted, and though the weathered surface is milky white the joint planes and cracks are stained with iron oxide. They show little mineralization, however. Few of these large quartz masses appear to occupy well-defined fissures; as a rule they seem to fill spaces of very irregular outline. The schists nearer them are always greatly disturbed, and the veins themselves are broken and crushed.

Small quartz veins, though less conspicuous, are far more numerous and here and there are well mineralized. They appear as small lenses, either lying in the cleavage or crossing it, as fillings along joint planes, and as narrow veins or flattened lenses of fairly regular thickness but small longitudinal extent. A broken surface of such a vein may show sulphides, such as pyrite, or more commonly a cavernous interior filled with iron oxide derived from the alteration of pyrite. Some of these veins are known from numerous assays to carry gold in small quantity.

Calcite veins are restricted to the limestone areas or at least to these areas and their immediate vicinity. They reach thicknesses of several feet at various exposures but like the quartz veins have not been found to continue horizontally for any considerable distance. It should be stated, however, that the lack of outcrops, due to the covering of loose weathered material or of moss, is a serious obstacle confronting the prospector who attempts to trace veins in this region and makes it quite impossible without much labor and expense to determine the course of the veins on the surface. Numerous calcite veins are exposed in the limestone area of Anvil Mountain and its continuation east of Dry Creek. Prospect holes have been sunk on some of them, and many have been staked as mining property. Free gold is found in small amount in some of these veins.

Besides the veins of quartz and calcite described above, there are also veins made up of quartz, chlorite, and albite. Most of these were observed in the Anvil and Newton Peak area. They were not

found in well-defined fissures and their forms are irregular. They are thought to have been deposited later than the small lenses and stringers in the schists, and so far as the writer knows they carry no gold.

SURFICIAL DEPOSITS.

The surficial deposits of the Nome region (see Pls. III and IV, in pocket) include accumulations of loose material that result from weathering processes without the sorting action of streams, lakes, or the sea and accumulations that were deposited in water. To the first of these belongs the material of angular and subangular form that is found on the tops and slopes of hills, gradually creeping down under the action of rain, melting snow, or frost to join or overlap the margins of the valley gravels. To the second class belong the elevated bench gravels, the stream and lake gravels, and the gravels and sands of the Nome coastal plain. The loose deposits resulting from glacial erosion and transportation belong in part to one class, in part to the other.

UNSORTED WASTE.

Two classes of unconsolidated fragmental material make up the unsorted waste of the Nome region. One class consists of the mantle of coarse and fine angular and subangular débris resulting from subaerial weathering, which is found on the tops but more especially on the slopes of hills. The other class includes part of the morainal accumulations left by glaciers and will be treated in connection with glacial deposits (pp. 51–52).

Most of the loose rock material on the slopes and tops of hills has received no further sorting by water than that brought about by rain and melting snow, and deposits of this kind do not take the orderly form seen in accumulations of gravel and sand laid down in streams or lakes. Much of the material has traveled only short distances or practically not at all, and such movement as has taken place is down the hill slope, except in the case of wind-blown sands or dust. This material represents the destruction of country rock brought about by the ordinary processes of weathering, especially that produced by change of temperature and the expansive power of freezing water. Although the material is properly described as angular, a small part of it is more or less rounded and might even be mistaken for water-worn material. This rounding is probably due in part to weathering, in part to the rubbing of the fragments as they creep down the slopes under the action of frost, rain, and gravity.

The forms taken by some of these slowly downward-moving accumulations constitute one of the noticeable features of the hills of

this region. The débris, consisting of fine and coarse material, in most places covered with vegetation, moves gradually down the hill slope in a manner resembling the movement of tar on a slightly inclined plane. Each individual flow, of which there are great numbers, shows on the lower edge a steep face from 1 foot to perhaps 6 or 7 feet high. The face does not extend straight along the hillside but consists of a series of lobes, the central part of each moving faster than the sides. In many places the advance is plainly made by a rolling movement, the upper part of the lobe pushing out beyond the lower and overhanging it. The general effect when viewed at a distance is that of a roof with irregularly laid tiles. It seems probable that frost and ice are more effective in moving these terrace-like bodies than the summer rain, and that the movement begins in the fall, when the "freeze up" comes, but takes place chiefly in the spring, when the frost goes out of the ground and leaves it in a soft, sometimes almost fluid, condition. The tendency of all this fragmental material is to travel slowly from higher to lower levels. Consequently it should have covered the margin of the water-laid valley and tundra gravels and in fact is found to have done so. This downward creep is one of the factors that have given rise to confusion between water-laid and unsorted material, especially among some of the tundra gravels.

STREAM GRAVEL.

Under the term stream gravel are described those gravel accumulations that are directly referable to present creeks or rivers or that compose the valley floors in which these streams are flowing. Part of the deposits lie considerably above the present watercourses and in places were laid down under conditions different from those now prevailing; yet they owe their formation to transportation and deposition by streams.

Most of the gravel deposits are frozen throughout the summer as well as during the winter. The exceptions include sand and gravel in stream channels, accumulations not covered by moss or muck, and irregular deposits that never freeze, probably because of water circulating in them.

The gravels found along a great majority of the small tributary creeks and gulches are of local origin, being derived from bedrock within the limits of the present drainage basins. The character of the material forming them will, therefore, depend on the character of the rock occurring in their own basins. South of the Kigluaik Mountains the gravels on most of the small streams consist almost entirely of schist and quartz, in many localities with limestone and greenstone. Much of the material is angular or subangular and the deposits are shallow. Within the Kigluaik Mountains also the grav-

els are of local origin, being derived from the schist, gneiss, and limestone formations of the Kigluaik group and from the intruded igneous rocks. They include an immense quantity of glacial bowlders and angular blocks.

In the larger stream valleys, such as those of Nome River or Snake River, the gravels are derived from more widely distributed sources and are consequently more heterogeneous in character. They contain not only material from the rocks of the Nome group but also some from the Kigluaik group. Such gravels have traveled farther and are more worn than gravels on the small streams. They contain, therefore, a greater proportion of fine gravel and sand, and in general there is greater uniformity in the size of their fragments. Angular material also is less abundant in them.

The greatest depth of stream or valley gravels known to the writer occurs at the place where Snake River leaves the hills to cross the coastal lowland. At a distance of 4 miles north from the coast the gravel accumulations near the river have a thickness of 75 to 100 feet, bedrock lying about 75 feet below sea level. It is therefore evident that they occupy a region which has been depressed, and it is even probable that the lower part of these gravels constitutes part of the coastal-plain deposits. From Goldbottom Creek, 10 miles farther north, down to this point Snake River flows in a widely meandering course over a gravel valley floor averaging between three-quarters of a mile and 1 mile in width. The thickness of these gravels has been tested in only a few places, but where examined is considerable.

Gravel of such depth as occurs on lower Snake River is not known in the Nome River Valley. From the mouth of Osborn Creek to Bering Sea bedrock lies below sea level, although along the river channel between Osborn Creek and Laurada Creek it is only a few feet lower. Where the gravel deposits of lower Nome River above Osborn Creek have been tested they were found to range in thickness from 10 to 40 feet. At Sparkle Creek the thickness of the gravel ranges from 58 to 73 feet and just below Sampson Creek from 49 to 60 feet. No records were obtained for the portion of Nome River above Sampson Creek. Nome River, like Snake River, flows over a broad gravel floor. Below Hobson Creek this valley floor has much the same character as that of Snake River, but above Hobson Creek the valley contracts and the amount of gravel filling decreases.

Extensive and deep deposits of gravel are present in the valleys of Sinuk River, Stewart River, Salmon Lake, and Flambeau River, but there are no drill records at hand showing their thickness.

ELEVATED BENCH GRAVEL.

The elevated bench gravel is treated separately from the stream and coastal-plain gravels, not because it is necessarily of a different

origin but because of its position. It is evident, then, that the distinction is in some measure arbitrary. The term refers to those deposits, excluding coastal-plain gravel, which lie above the influence of the present streams and whose deposition therefore does not appear to be referable to them.

The bench gravels are best known in the southern part of the Nome quadrangle, because they here carry gold in sufficient amount to be of economic value. They are made up of the same kinds of material that are found in the other gravel deposits—waste from the rocks of both the Nome and Kigluaik groups.

The more important accumulations occur in the saddles between Deer Gulch and Nekula Gulch, between Grass Gulch and Specimen Gulch, between Dry Creek and the Left Fork of Dexter Creek, and on the south side of King Mountain. (See fig. 9, p. 78.)

At the first-named locality, just north of Dexter station on the Seward Peninsula Railway, the depth of gravel is between 130 and 140 feet, but a quarter of a mile east of the station a shaft was sunk 130 feet through gravel to what was apparently a schist ledge and then with a slight offset was continued 100 feet deeper to bedrock. The gravel consists of schist and quartz with a few pebbles of granite. It is possible, however, that the granite occurs only at the surface. The appearance of the gravel shows it to be stream wash. A further indication of this is that two "pay streaks," representing old stream beds at different levels, led from the saddle southeastward across the point of the hill. The lowest depression of bedrock in this saddle lies near the head of Nekula Gulch but is filled by gravel, and the drainage divide is at Dexter station, several hundred feet southeast, so that water which, if the gravel were removed, would reach the sea by way of Dexter Creek and Nome River now reaches it by way of Anvil Creek and Snake River.

The gravel in the divide between Grass Gulch and Anvil Creek has a depth of 110 feet and fills a comparatively narrow channel. A very marked difference between this deposit and that at Dexter is the much greater quantity of granite and other foreign bowlders here. This granite débris is found at the surface and continues southeast toward Dry Creek and southwest into the Anvil Creek valley. The gravel in the saddle between Dry and Dexter creeks is shallower than that in the other two localities and contains almost no granite.

A filling of gravel and sand occurs also in the saddle separating the two round hills between Buster and Osborn creeks. The driller who investigated this locality reported that his drill passed through 6 to 10 feet of gravel, 90 feet of muck with yellow mud and ruby sand, and 20 feet of clear ice into an unknown depth of sands and gravel containing much water.

Gravels are found also in some of the low saddles along Nome River, such as that at the head of Darling Creek, but whether they are related in origin to those already mentioned is uncertain.

COASTAL-PLAIN GRAVEL.

The coastal-plain or tundra gravel occupies the crescent-shaped area included between the sea and the hills and extending from Cape Nome to Rodney Creek, 14 miles west of the mouth of Snake River. Only the eastern half of this crescent lies within the Nome quadrangle.

This coastal lowland consists of a great accumulation of fragmental material, silt, and fine sand interstratified with well-rounded gravels and beds containing finer stream wash, together with angular slabs and blocks up to 2 feet or more in greatest diameter. With the exception of comparatively small areas, these deposits are frozen from top to bottom. Beds of pure ice appear near the surface in many places. The rock here is similar to that which occurs in the streams of the large valleys, including schist, quartz, limestone, and various eruptives derived from the Nome and Kigluaik groups. Most of the very coarse angular material consists of schist, and a small proportion is limestone. Granite was not found in beds of this character, but large bowlders of granite, worn and more or less rounded, occur at the surface. Flattened and striated limestone fragments also are found near the surface. Much the greater part of these surficial accumulations was laid down by the sea or by streams, but there is a considerable portion whose present condition is the result of subaerial weathering and a much smaller part which was probably brought here by floating ice.

Since the discovery of gold in the old beaches of the tundra and more especially since the very rich beach placers of Little Creek became known a large number of shafts have been sunk in various parts of the coastal lowland and a much greater number of holes have been drilled. These shafts and drill holes have given most of the information obtained concerning the gravels.

Near the coast by far the greater part of the gravel was laid down originally in the sea or has been sorted and redeposited by its action. Farther north, near the hills, only the lower beds are of marine origin and the upper ones are stream-laid or represent the débris creeping down from the hill slopes.

In some places marine gravels and stream deposits may be recognized without much difficulty, but in others the two grade into each other. It is especially hard, at some points perhaps impossible, to distinguish them near the mouths of streams that brought a large quantity of rock waste into the sea, as at Little Creek, while the beach deposits were forming. As a rule, the marine sediments are cleaner, more rounded, and more thoroughly sorted than the stream wash.

Beds of "ruby sand" (garnet) are common. Stratification is apt to be obscure in the thick heavy beds, but beds of fine and those of coarse material and also beds of different materials are usually sharply separated from each other. From a number of shafts marine shells have been obtained.

The stream wash, on the other hand, comprises both rounded and angular or subangular fragments. It contains less quartz and does not show the wear that characterizes beach deposits. It further contains a large amount of mud and is less distinctly stratified. Stream gravels may be confused with unsorted débris, which rain and frost carry from the hill slopes out over the margins of the sedimentary accumulations.

The numerous shafts and drifts along the buried ancient beaches give the best exposures of the tundra deposits. Two well-defined shore lines of this sort have been explored nearly from end to end, and others are known. The one nearer the sea lies about two-thirds of a mile from the present beach at Nome and extends eastward to a point within a short distance of Cape Nome, but here its distance from the coast is less. At Hastings Creek it lies about one-fourth of a mile from the coast, but east of that locality its position is not known and it appears to have been removed through erosion. Its elevation above sea level is 37 feet, and its location is indicated in places by a moss-covered gravel scarp at whose foot it lies.

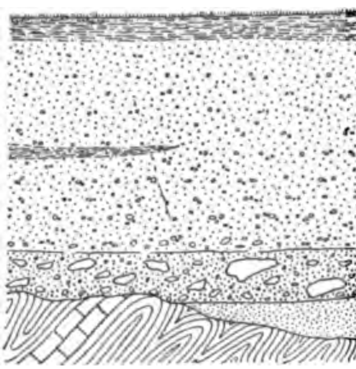


FIGURE 3.—Generalized section of gravel deposits north of Nome, on the third beach.

The other buried beach is definitely located from Little Creek, where it is crossed by the railroad tracks, to McDonald Creek, a distance slightly more than 5 miles. It has been traced between these points in a line slightly bowed toward the north like the present beach, yet showing slight undulations, and is interrupted by the valleys of Nome River, Anvil Creek, and Snake River, whose streams lie below its level. Its elevation above sea, from reliable information obtained at Nome, is 79 feet. These two old shore lines are generally known as the second and third beaches, the present beach being counted as the first.

A generalized section (fig. 3) of the deposits exposed along the third beach shows gravel or sandy gravel with coarse bowlders resting either on schist bedrock in which are a few limestone beds or, as

at the east end of the beach, on fine sands, which in turn rest on schist bedrock. Above this is a considerable body of gravel overlain by "muck" and the surface vegetable matter. This general section, however, is subject to wide variations. The thickness of the "muck" ranges from 1 foot to 15 feet or more. A blue clay is found underlying the "muck" in several shafts. In places a heavy wash, consisting chiefly of schist, occurs near the surface. At some points the gravels are slightly cemented by the deposition of lime or iron oxide. Marine gravels are interbedded with creek wash. The character of the material varies in both composition and coarseness. In fact, as previously stated, the deposits where first exposed on Little Creek were so varied in appearance and manner of deposition as to cause some geologists to doubt whether any of them were of marine origin.

Only part of the shafts on the second beach have been sunk to bedrock, as the pay streak in most places lies on a false bedrock of clay or sandy clay and gravel. There are not many data, then, on which a complete generalized section can be based, but apparently coarse angular material, although by no means lacking, is not as abundant as on the third beach line. The quantity of garnet ("ruby sand") is also far greater on the third beach. This is probably accounted for by the fact that much of the material of the third beach has traveled a shorter distance from its source and has been less subject to wear by streams and waves.

In 1907 and 1908, after the field work on which this report is based was completed, a number of other buried beaches were discovered, but much less is known of them than of those already mentioned. The "intermediate" beach is between the second and third beaches and has an elevation of 22 feet above sea level. It is thus lower than the second beach. One of the prospect holes on this beach was examined by Smith,[1] who says:

> At this place the bedrock consists of black, graphitic, somewhat quartzitic schist breaking into small rectangular blocks. The pay gravel is made up of poorly rounded schist fragments mixed with a good deal of mud. The gravels are very dirty. Above, in the south end of the drift, there is a sand layer, which rises very steeply toward the north. In the north end there is a thin layer of muck between the pay gravels and an overlying bed made up of large bowlders. The bowlders are well rounded, and some of them are 2 feet in length. Marine shells were found in the "intermediate" beach near Center Creek.

The two so-called "submarine beaches" lie between the second beach and the present beach. They have been described by Smith[2] as follows:

> The easternmost of the properties on this beach is located on the coastal plain just west of Snake River and almost directly south of the pumping plant, a

[1] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey No. 345, 1908, p. 215.

[2] Smith, P. S., Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, p. 271-278.

quarter of a mile north of the present beach. The ground has been opened by means of two shafts, the eastern of which has a depth of 69 feet and the western of about 65 feet. At this place the pay streak is 19.6 feet below sea level and for that reason the beach is called the "submarine." * * *

The unconsolidated deposits at this place consist of irregularly distributed alternations of gravel and sand, the latter usually forming the base of the section. Many of the sandy layers show abrupt terminations which seem to have been formed by faults, but none of these dislocations could be traced into the gravel lenses. In the gravel beds pebbles of all kinds of rocks were found. Numerous fragments of black slate, similar to that occurring in places as the bedrock of the "third beach" and in the hills back of Nome, were seen, as well as various schist and limestone pebbles. Feldspathic schist and greenstone fragments, however, form only a small percentage of the deposit. It is interesting to note in this connection that several blocks of granite were also found in the gravels. The significance of this lies in the fact that the granite fragments are similar to the granite of the Kigluaik Mountains, and the conclusion is practically inevitable that they must have been derived from this source. In the gravels some large blocks of quartz were found, some of them 2 feet in longest dimension. Their general outline was more or less angular, but their corners were well rounded, and they had all the appearance of having been water worn. No constant direction of the shingling of the gravel deposits was observed, and it would appear that deposition was effected by strong variable currents such as would be expected to occur near a shore line.

In the west end of the southern drift a series of ramifying streaks of a black peaty material cut in irregular directions across the layers of sand and gravel. Because of the difference in color these bands are far more noticeable where they cut across the light-brownish sand, but a careful search shows that they are almost equally numerous in the coarser gravel layers. Pebbles showing well waterworn outlines are scattered irregularly but not abundantly in these peaty seams. When first examined it was believed that they represented cracks which had been subsequently filled by material from the surface. Similar cracks are observed at the present time in many places where the melting of the ground ice allows settling and cracking of the deposit previously formed. In the light of more careful study, however, such an interpretation seems inadequate, for many of the seams taper off toward the top as well as toward the bottom, so that a connection with the surface is not indicated. It is believed that their occurrence is due in some way to the settling of the ground subsequent to the formation of a part at least of the gravel deposits, but the information concerning these seams is as yet too meager to allow an explanation of their origin. Although as the matter now stands an explanation of these seams does not appear to be directly connected with the economic problems, it is believed to be important, for everything which throws light on the physical conditions under which the coastal-plain deposits were formed should assist in determining the factors which led to the deposition of the economically valuable placers in this area.

In the north end of the eastern drift a layer of sand with a few pebbles scattered irregularly through it lies underneath a gravel deposit, only the base of which is exposed in the drift. This sand bed is interesting because it contains numerous shells that can be used in determining the relative age of the gravels at this point. The most abundant of the shells is one that is large and clamlike, but numerous other fossils also abound. All the shells occur in the sand layer, none being found in the overlying coarser gravel. The physical condition of these shells is interesting and, it is believed, throws some light on the relative age of this beach and the earlier known and previously described

beaches. Practically none of the shells show water rounding or other evidence of having been subjected to the pounding of surf, but in spite of this almost all are broken into small bits or are so decomposed that it is almost impossible to remove them from the layers in which they occur. Such a condition would seem to indicate that they have undergone a large amount of decomposition and fracturing since they were laid down. When it is remembered that the shells found on many of the beaches farther inland, such as the "intermediate beach," are practically undecomposed, the suggestion that the "submarine beach" is much older than the others receives considerable support from the physical character of the fossils.

There is some reason for thinking that the tundra deposits gradually increase in thickness from the south toward the north and reach a maximum somewhere in the vicinity of the third beach. North of that beach they decrease rapidly till they disappear on the lower hill slopes of the plateau area. This condition, though it may not be true of all places, is well brought out in the section shown in figure 4, compiled from records of drilling along Bourbon Creek

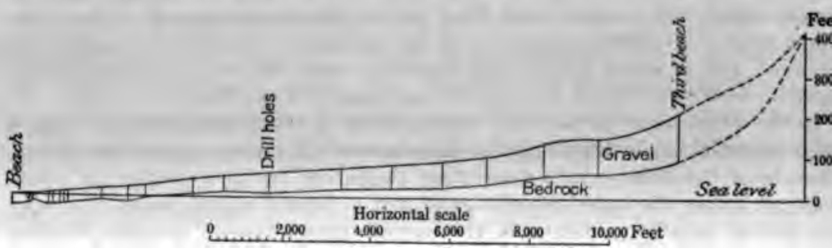


FIGURE 4.—Section of coastal-plain gravel deposits along Bourbon Creek.

from a short distance north of the beach to the hills. The drilling was done near the stream channel and therefore shows a less thickness of deposits than would appear if the holes had been placed at a distance from it. The shallowest hole is 17 feet deep and the deepest 120 feet. Between the two the increase is fairly regular.

Although this statement concerning the increasing thickness of gravels toward the north is believed to be true in general, it must not be expected to hold true in every individual case, for there is considerable unevenness in the bedrock surface beneath the gravel. This surface may and undoubtedly does differ greatly from the upper surface of the gravels. As an example of this difference may be mentioned the fact that a well at the Golden Gate Hotel in Nome was put down 140 feet before striking bedrock, whereas the depth of gravel along lower Bourbon Creek averages not far from 20 feet.

Marine shells were found in the coastal-plain gravel at several places during the course of the field work and may be seen in the dumps from some of the shafts. Many of them are in an almost perfect state of preservation, which suggests that they accumulated in comparatively quiet water. Two localities furnished most of the collection submitted for determination. Near Center Creek, almost

2 miles from the coast, they occur in gravels 32 feet below the surface and at an elevation of about 20 feet above sea level. Two forms collected from this locality were determined by W. H. Dall as *Pecten* (*Chamys*) *swiftii* Bernhardi, now living at Hakodate, Japan, and *Maconia middledorffii* Dall, now living only south of the line of winter ice in Bering Sea. = PROBABLY MACOMA MIDDENDORFFII DALL

A larger collection was obtained from Otter Creek,[1] 2 miles from the coast. They were found 50 feet below the surface, at an elevation of 20 feet above the sea. At this locality they are very numerous, and may be obtained without difficulty. The collection was submitted to Mr. Dall, who divides them into two classes, those now living south of the line of winter ice and those living both north and south of it.

Species now living south of the winter ice line in Bering Sea:
- Monia macroschisma Dall.
- Panomya ampla Dall.
- Pecten[2] n. sp., temperate type.

Species now living north and south of the ice line:
- Barnacle, Balanus sp.
- Cardium, sp. undet.
- Hemithyris psittacea L.
- Macoma sabulosa Spengler.
- Pecten islandicus Müller.
- Venericardia alaskana Dall.
- Venericardia crassidens Brod. and Sby.

Several of these forms, particularly *Venericardia crassidens* and *Macoma sabulosa*, do not appear in the longer list that follows. Mr. Dall says of these fossils: "The shells from Nome are most interesting. They are probably Pliocene, and show conclusively a milder climate than now prevails there—say, something like that of the Aleutians or north Japan."

These fossils came from the lowest part of the tundra gravels. No fossils appear in the surface water-laid gravel, much of which is not marine, or if it was deposited by the sea has since been reworked by streams.

Pieces of wood and walrus tusks have been found in the sands of the second beach and are much later than the gravel from which the shells above-mentioned were collected.

Very much larger collections of shells were made from the tundra gravels by E. M. Kindle in 1908. Mr. Kindle also made collections of marine shells of forms now living along the coasts of Seward Peninsula, which are of interest because they show that about one-

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[1] Most of the shells from Otter Creek were obtained through the kindness of Mr. J. J. V. Beaver, of Nome.

[2] Dall, W. H., On climatic conditions at Nome, Alaska, during the Pliocene, and on a new species of Pecten from the Nome gold-bearing gravels: Am. Jour. Sci., 4th ser., vol. 23, pp. 457–458.

third of the fossil forms are those of living species. Lists of these collections are given below. Shells are rare on the Nome beach, and that locality is not represented in the lists, but all the shells, with one exception, were obtained within 150 miles of Nome. The determinations were made by Mr. Dall.

Marine shells from the old beaches in the vicinity of Nome.

	1. Submarine beach, ¼ mile west of Snake River.	2. Submarine beach near locality 1.	3. Center Creek.	4. Galatin claim, Otter Creek.	5. Submarine beach ¾ mile west of Nome.	6. Near locality 5.	7. Black Diamond claim, near Tripple Creek.	8. Near locality 7.	9. Second beach, 1¼ miles east of Nome.	10. Second beach, ¾ mile east of Nome.	11. Cyrus Noble claim, third beach.
BRACHIOPODA.											
Hemithyris psittacea Gmel				×			×	×	×		
Magasella aleutica Dall							×	×			
CRUSTACEA.											
Balanus aff. crenatus Darwin			×					×	×		
aff. hameri Darwin			×								
MOLLUSCA.											
Astarte near striata Leach	×					×					
n. sp	×		×	×					×	×	
Buccinum sp., fragments	×								×		
Cardium sp., fragments	×										
ciliatum Fabr			×	×		×			×	×	
Chrysodomus n. sp., fragments			×								
aff. lirata Martyn			×								
sp. ind	×		×								
Cryptobranchia n. sp			×							×	
Littorina n. sp. aff. palliata Say										×	
n. sp.?, aff. grandis Midd										×	
Macoma middendorffii Dall		×	×						×	×	
rotundata Sby			×						×	×	
sp., fragments	×					×					
Monia macroschisma Deshayes			×	×					×	×	
Mya sp., fragments	×		×			×					
arenaria L			×								
truncata L			×						×		
Mytilus edulis L		×	×			×			×		
Panomya ampla Dall			×						×		
norvegica Spengler?			×								
sp., fragments				×							
New genus (allied to Panomya), fragments	×										
Pecten swiftii Bernhardi			×	×					×		
(Chalmys) lioicus Dall				×							
Pecten? islandicus Müller								×			
Purpura n. sp. near crispata			×								
(Thais) sp., fragments	×										
cf. lima Martyn, fragments		×				×					×
Rictocyma n. sp	×										
Saxicava artica L			×	×					×		
rugosa L					×						
Serripes grönlandicus		×							×		
Siliqua sp. aff. patula Dixon			×								
Spisula alaskana Dall		×	×	×						×	
Thais n. sp. aff. lamellosus Gmel			×								
aff. lima Martyn, fragments								×		×	
Trichotropis insignis Midd			×						×		
Venericardia alaskana Dall	×?		×	×					×		

Recent marine shells from Seward Peninsula and vicinity.

	Cape Prince of Wales.	Deering.	5 miles east of Deering.	Cape Decoit.	Cape York.	Lost River.	Point Hope.
BRACHIOPODA.							
Hemithyris psittacea Gmel		×					
MOLLUSCA.							
Acmæa testudinalis Müller	×	×	×				
Admete couthouyi Jay	×						
Æirsa borealis Beck	×						
Amouropsis purpurea Dall	×		×	×			
Arctoscala grönlandica Perry	×						
Astarte borealis Schum		×	×				
near striata Leach	×			×			
vernicosa Dall			×				
Bela sp. indet		×					
lævigata Dall		×					
simplex Midd	×						
Buccinum angulatum var. normale Dall	×		×				
angulatum var			×				
polare Gray	×						
glaciale Ph							×
tenue Gray	×						
Bulbus flavus Gould	×						
Cancellaria middendorffii Dall	×						
Cardium californiense Desh	×		×				
ciliatum Fabr	×	×					
Chrysodomus fornicatus Gray	×		×	×			×
liratus var.?	×	×					
spitzbergensis Reeve	×						
Drillia kennicotti Dall	×						
Fuspira pallida Brod	×			×			
Liomesus canaliculatum Dall	×						
ooides Midd	×						
Littorina grandis Midd				×	×		×
Lunatia pallida Brod. and Sby	×	×					
Macoma carlottensis Whiteaves	×	×	×	×			×
inconspicua Brod. and Sby	×		×	×			
Margarites albula Gould	×						
striata Brod. and Sby		×					
Modiolaria lævigata Gray			×				
nigra Gray	×						
Mya arenaria L	×						
truncata L	×						
Mytilus edulis L	×	×	×	×		×	
Natica clausa Brod. and Sby	×	×	×	×		×	
Pecten islandicus Müller	×						
Purpura lima Martyn	×						
Saxicava arctica L	×						×
Serripes grönlandicus Müller	×						×
Siliqua media Gray	×		×	×			×
Solariella albula Gould	×						
cinerea Couth	×						
Spisula alaskana Dall	×						
Tachyrhynchus polaris Beck	×						
Tellina alternidentata	×						×
Thais lima Martyn	×						
Trichotropis arctica Midd	×						
Valvata mergella West			×				
Velutina velutina Müller			×				
Venericardia alaskana Dall	×						
Volutopsius attenuatus Dall	×						

Mr. Dall concludes from his study of the faunas from the buried beaches at Nome that the gravels of the so-called "submarine" beach are either Pliocene or upper Miocene, and that the remaining gravels, so far as their age is determined by the shells given in the lists, are undoubtedly Pliocene. The relative age of the "submarine," "intermediate," and "third" beaches is indicated by the

order in which they are named, the "submarine" beach being oldest.

The order of formation and relative age of the buried be have been given in some detail by Smith,[1] from whom the follo is quoted:

From the present evidence it would seem that the earliest event re definitely in the history of the region is the formation of the "outer subm beach." What the condition of the region was prior to this incident known, but it is probable that the older coastal-plain deposits had formed and were eroded by the waves to form this beach. After the beach had progressed to a certain stage gradual depression with respect sea brought the shore line at the level of the "inner submarine beach." amount of this depression must have been about 14 feet. Still later fu subsidence of about 42 feet brought sea level to the elevation of the " mediate beach." The movement continued and the land sank with re to the sea about 56 feet, so that the shore line was on the level of the " beach." After remaining for some time in this position further depre took place, and the sea attacked the schist and limestone bluffs which

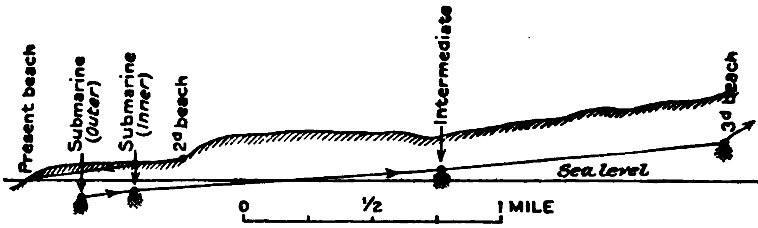


FIGURE 5.—Diagrammatic cross section showing beaches near Nome. Vertical scale a 12 times horizontal.

steeply about half a mile north of the "third beach." While each of beaches was being formed by the sea, deposition was taking place on the floor, and sands and gravels brought down by the rivers and worn from cliffs by the waves were covering the earlier beaches, thus producing a face such as the sea floor of the present day might show if it could be amined.

After the shore line had taken a position landward of the "third beach" change in the progressive depression of the land took place, and uplift beg The result of the uplift was to cause more and more land to emerge fr beneath the sea. The uplift seems to have gone on at first without any int ruption, for there are no signs of long halts and the accompanying formati of beaches on the surface of the coastal plain. At length, however, when t shore line was some distance south of the "second beach," a period of relati stability ensued, and the sea gradually cut back into the coastal-plain gravel until a cliff, in places nearly 75 feet high, towered above the beach. Thi feature can be most plainly seen in the vicinity of Rocker and Martin gulches a little east of Nome. When this stage of cutting had been reached an uplift of about 38 feet brought the shore line to a short distance seaward of its present position, and then, in a period of stability, the sea renewed its cutting on the shore and formed the low cliff which rises from the present beach.

[1] Smith, P. S., Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, pp. 277–279.

According to this interpretation the recognizable portion of the history of the coastal plain shows an earlier series of depressions amounting to between 100 and 200 feet, followed by an uplift of about 34 feet less. That there were oscillations in these movements can not be doubted, but that the sum of the changes of level was of the character noted seems obvious. The absence of all surface topographic forms characteristic of beaches, save in connection with the present, the "second," and the most inland beaches, seems to indicate conclusively that these three were the last ones formed and have not been subjected to marine erosion since their formation. Furthermore, the condition and character of the fossils already described would seem to substantiate this conclusion.

SILT.

One of the most widespread of the surficial deposits is the covering of "muck" or silt present throughout the whole of Seward Peninsula and in many other parts of Alaska as well. It is present everywhere on the Nome tundra and on all the gentle lower hill slopes and the valley floors, though it is not usually found on the flood plains of the streams. In consists of finely divided rock particles, much finer than ordinary sand, with more or less vegetable matter, and its color is black or bluish gray. There is scarcely any coarse material in it. Its thickness ranges from a few inches to 15 feet or more. It is frozen and is covered by low vegetation, which is a poor conductor of heat and protects it from thawing. When the vegetation is removed the "muck" becomes a thin mud and flows readily. This fact accounts for the origin and growth of many of the small ponds scattered over the Nome tundra.

In some parts of Seward Peninsula thin lenses and veins of ice give some of the muck a brecciated appearance. Larger beds of ice occur in the muck, but the ice beds of greatest thickness are found below the muck and overlying the gravel. These thick ice beds are not everywhere present and are most likely to be found along the streams. The blanket of vegetation above protects the muck and ice and the gravel deposits from sun and rain and keeps them always frozen. When the gravels are uncovered they thaw, but whether the deep gravels would thaw to the bottom is an unanswered though highly important question.

Concerning the origin of the muck and the manner in which the ice beds formed there is some difference of opinion. Brooks,[1] in a recent description of the hill slopes of the Dahl Creek region on Kaugarok River, states the "muck" to be "a subaerial accumulation due in part to the decay of vegetable matter, in part to the deposition of silts during the rainy season." This idea was not put forward as a general explanation of all the silts, though it may be said

[1] Brooks, A. H., The Kougarok region: Bull. U. S. Geol. Survey No. 314, 1907, p. 168.

that they contain much vegetable matter and are most highly developed on the lowlands, as would be the case if they were made up of the finer material from the weathering of the hills above them. Against this hypothesis may be urged the fact that some of the silts occur at long distances from the hills and in places where it is difficult to see how they could accumulate under present conditions. Such accumulations are the low cliffs along the beach, where the frozen silts have a thickness of 8 or 10 feet in places. The silts are not derived by decomposition from the gravels under them, for the line between the two is always sharply drawn and the silt is fresh and angular, containing little or no coarse material.

Another and more widely applicable explanation of the silts is that they accumulated under water, either in the sea during a period of land subsidence or possibly in fresh water. Subsidence of the land in recent time is shown in many parts of the peninsula by abundant evidence, some of which is given in the discussion of the coastal-plain gravels. It is not improbable that part or all of the silt in some regions, such as the Kuzitrin lowland above the mouth of Kougarok River, could have accumulated in fresh water, but its distribution is too widespread to be accounted for entirely by causes of so local a nature.

The character of the material suggests that part of it at least may be the fine rock flour ground up by glaciers, yet here again its widespread distribution seems to raise an objection to this theory of its origin, for there is no evidence at hand to show the existence of glaciers of sufficient extent to account for all the deposits of this kind on Seward Peninsula, perhaps not even for those of the area here discussed.

In places on Seward Peninsula portions of trees and bones of animals are embedded in the silt. These bones include teeth of a horse, probably *Equus complicatus*, and teeth and tusks of a mammoth (*Elephas primigenius*). The trunks, bark, branches, and cones of spruce trees represent the only species of wood known to be present.[1] The condition of the logs is such as to suggest that they are driftwood accumulations, much like those seen on the Nome beach when the region was first visited and still remaining in a few places. There are objections, however, to the view that the silts are of marine origin. It is difficult to see how, if they were exposed to the force of waves, they could remain on such slopes as the coastal plain while that plain was gradually emerging from the sea. A stream of water cuts through them as it would through ice, and where exposed on the hillside by removal of the vegetation they rapidly wear away. The organic matter present is another objection, for it is so widely

[1] Collier, A. J., A reconnaissance in northwestern Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 27.

distributed that apparently it must have been incorporated with the silts originally. It seems improbable that such an amount of organic matter would be found in marine sediments of this nature, unless they were deposited in protected and possibly shallow waters. Doubtless the silts have been modified in places by stream action, but to what extent is not known. Erosion and redeposition would account for some of the variability in thickness and also for the fact that the silts are not found on the tops or high on the slopes of hills.

It appears probable that these silt deposits are not due to any single cause and that each of the methods of deposition that have been mentioned may be represented by examples on Seward Peninsula or even in the smaller area of the Nome region. The hypothesis of subaerial accumulation due to the settling of wind-blown particles offers an explanation that is more in accord with the conditions in many localities than either of the other two, but it is evident that if the climatic conditions of the more recent past were similar to those of the present accumulation by this method must have gone on very slowly. For many parts of Seward Peninsula glaciation as an explanation for the origin of the silts is not satisfactory in view of present knowledge of the extent of glaciation on the peninsula, for the distribution of the silts is far wider than that of the ice, so far as has yet been shown.

GLACIAL DEPOSITS.

Débris transported by glacial ice is finally deposited at the end or sides of the glacier, or is left on its bed when the ice disappears. Part of this débris is carried way and deposited by streams flowing from the glacier, or is laid down in glacial lakes or ponds. A second part is not transported or sorted by water, but is laid down in confused masses as morainic material

Such accumulations are present in nearly all the valleys of streams of the Kigluaik Mountains shown on the map, but more especially in the larger ones, such as those of Windy Creek, Sinuk River, and Grand Central River, also at the head of Nome River and in Salmon Lake valley. A terminal moraine consisting of immense blocks of granite and schist crosses the valley of Windy Creek just below the small lake represented near the northern margin of the Grand Central map (Pl. IV, in pocket). Another moraine extends out from Thompson Creek and forms a low barrier halfway across the Grand Central River valley. A small moraine is seen on Fox Creek, north of Salmon Lake. Mounds of morainic débris occur at the head of Nome River and on the divide between Nome River and Salmon Lake. The most abundant of the glacial deposits, however, consist of blocks and bowlders scattered over the valley floors within the Kigluaik Mountains. They do not generally form conspicuous

mounds or ridges, but are strewn about in many places just as they were left by the disappearing ice.

Erratic bowlders are found in the valley of Nome River and are distributed generally over the tundra, but whether or not these were left by glacial ice is difficult to decide. The better knowledge of the deposits of the Nome tundra that has come with the development of the gold placers leads to the belief that glaciation was more extensive in this region than was for a long time supposed. Smoothed and striated bowlders are abundant in the gravel accumulations of the coastal plain, and, as has already been pointed out, the fine rock flour from the glaciers may be one of the sources for the material of the silt deposits. There is still little reason to question the conclusion of earlier workers that Seward Peninsula has not been subjected to regional glaciation. All observers have been impressed by the peculiar monument-like residual rock masses (Pl. IX, *B*) resulting from weathering that are seen on the tops of certain hills, and have argued that these hills could never have been covered by a sheet of moving ice unless the monuments were formed since the ice retreated. It is nevertheless highly probable that the valleys of Nome and Snake rivers have been occupied by ice that moved down almost, if not quite, to the coast. Possibly the lower mountains between the coast and the Kigluaik Mountains have been centers of accumulation, although the forms of the valleys, except that of Christian Creek, do not lend much support to this idea. The Kigluaik Mountains, however, were an important center of ice accumulation, and without question contributed ice to the valleys of Nome and Stewart rivers. Granite bowlders from the Kigluaik Mountains are abundant on the south side of Stewart River up to an elevation of nearly 900 feet above the sea, but the ice must have reached higher on the valley wall than this, for the bowlders were carried from Bowlder Creek to Grouse Creek over a divide whose present elevation is 1,041 feet. A rounded granite bowlder was found on the west side of Mount Distin at a still greater elevation, so it is evident that the ice could have moved readily from the Stewart River valley to the head of Snake River, for the divide between these streams is only 633 feet above the sea. There are many granite bowlders in Grub Gulch, but a large part of the morainal débris in this gulch came over the saddle between it and Trout Creek. The numerous granite bowlders at the heads of Dexter and Anvil creeks are believed to owe their presence there, in part at least, to the same means of transportation. The Nome River valley must have offered a more favorable channel for ice movement from the north than any other valley within the Nome and Grand Central quadrangles and was probably occupied by an ice stream of considerable size.

A. SUMMER REMNANTS OF AN ICE SHEET THAT COVERED THE FLOOD PLAIN OF A STREAM DURING THE PRECEDING WINTER.

A layer of gravel and sand lies on the blocks of ice and prevents them from thawing.

B. TYPICAL SCHIST "MONUMENT," AN EROSIONAL FEATURE COMMON IN MANY PARTS OF SEWARD PENINSULA.

ICE BEDS.

Beds of clear ice occur very commonly with the gravel deposits of the streams and the Nome tundra. The ice beds are associated more closely with the silt deposits than with the underlying gravels, although most of the gravels are frozen. Most of the ice beds are either in the silt or between the silt and the underlying gravel. Veins of ice in some places cut across the silt beds, and in general ice forms a considerable proportion of the silt deposits.

Ice beds, where associated with stream gravels, are found along the lower valley slopes between the hills and stream channels. They are always overlain by a protective covering of some kind, either silt or moss, and consequently are not present on the flood plains of the streams. In some localities they are absent altogether, and in others they reach a thickness of several feet. Beds of ice from 12 to 15 feet thick are not unusual along the streams in the Kotzebue Sound region.

The distribution of ice beds in the coastal plain about Nome is irregular and depends on conditions that are not understood. The beds do not differ in appearance or position from those of the stream valleys and probably were formed in much the same way. As a rule they are almost free from silt or gravel, although the exposed faces do not appear so, being covered by thin mud from the thawing silts above.

Concerning the formation of the ice beds of this region and of Alaska in general there is great difference of opinion, and it is evident that the last word on the subject has not been said. Two methods of origin have been given for such beds as are found along the streams in the Nome region—(1) that they are accumulations of winter snow, which were covered by gravel or silt and vegetation and thus preserved from the warmer weather of summer, or (2) that they were formed in place along planes of porosity within or under the silts after the silts were laid down. The burial of ice under a thin covering of gravel by spring floods is a common occurrence on streams of the Nome region. On such of these streams as have wide flood plains and low gradients broad sheets of ice and snow accumulate, some of which even if unprotected last into the summer. Many such ice sheets, however, or portions of them, are covered during the floods of early spring by a few inches of sand or fine gravel, and when thus protected, especially if so situated that the stream does not reach them, they may last throughout the summer. Such gravel-covered ice masses are seen in Plate IX, *A*. The second view concerning the origin of the ice beds has been pre-

sented, especially by Tyrrell,[1] whose observations were made chiefly in the Klondike gold-bearing district of Yukon Territory. According to Tyrrell the process is somewhat as follows:

Water issuing from the rock beneath a layer of alluvial material rises through the alluvium and in summer spreads out on the surface, tending to keep it constantly wet over a considerable area. In winter, if the flow of water is large and the surface consists of incoherent gravel, the water will still rise to the surface and there form a mound of ice. If, on the contrary, the flow from the spring is not large and the ground is covered with a coherent mass of vegetable material, such as is formed by a sphagnum bog, the spring water, already at a temperature of 32° F., rises until it comes within the influence of the low temperature of the atmosphere above and freezes. This process goes on, the ice continuing to form downward as the cold of the winter increases, until, a few feet below the surface but still within the influence of the low external temperature, a plane of weakness is reached in the stratified and frozen vegetable or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand.

As any outlet to the top is now permanently blocked, the water is forced along this plane of weakness and there freezes, and thus the horizontal extension of the sheet of ice is begun. While thus increasing in extent the ice also increases in thickness by additions from beneath, until it has attained a sufficient thickness so that its bottom plane is beyond the reach of the low atmospheric temperature above, after which it continues to increase in exent but not in thickness or depth.

With the advent of the warm weather of summer the growth of the crystosphene ceases; but the cold spring water which continues to rise up beneath it has very little power to melt it, and its covering of moss or muck, being an excellent nonconductor of heat, protects it from the sun and wind and prevents it from thawing and disappearing. Thus at the advent of another winter it is ready for still greater growth.

A third method by which ice beds or "glaciers," as they are locally named, might be formed, is mentioned by Maddren.[2]

An hypothesis to explain the occurrence of ice sheets under a mantle of moss under some of the circumstances where it is met with, especially on sloping surfaces such as Tyrrell describes for the Klondike region and which are common elsewhere in Alaska, is similar to a suggestion made by Lieut. Belcher.

The water sinks through the moss blanket from the surface and also seeps underneath it from higher levels. This tends to lift the living moss with its thawed underlying layer of vegetable humus or peat, floating it in a state of semibuoyancy above the frozen substratum of alluvium or peat, so the ice may accumulate season after season, as long as * * * equilibrium [is] maintained between the annually thawed peaty superstratum and the constantly frozen substratum.

There can be no question that veins of ice such as are seen cutting the silts in many places were formed after the silts were laid down, so there seems to be no serious objection to supposing that at least some of the ice beds could have been formed in this way.

[1] Tyrrell, J. B., Crystosphenes or buried sheets of ice in the tundra of North America: Jour. Geology, vol. 12, 1904, p. 236.

[2] Maddren, A. G., Smithsonian exploration in Alaska in 1904, in search of mammoth and other fossil remains: Smithsonian Misc. Coll., vol. 49, pp. 44-45.

STRUCTURE.

The structure of the Kigluaik group within the area mapped is apparently far simpler than that of the Nome group. Within the Grand Central quadrangle all the members of the Kigluaik group have a comparatively low and fairly uniform dip, in most places not over 30° or 35°, toward the southeast or south-southeast. (See fig. 6.) The strike of the beds does not vary greatly. Folding is not general, so that reversals of the dip are uncommon and only local; where northwesterly dips occur the beds stand at high angles.

By far the greater part of the igneous intrusions conform to the bedding and cleavage of the schists, even the large granite mass in the northwestern part of the area following this general rule. The thin limestone bed which overlies it in the Windy Creek valley can be traced for 2 miles along the contact. There is little evidence of faulting, and the upper part of the series appears to be decidedly less disturbed than many portions of the Nome group on the south. The lower part of the Kigluaik group, however, which does not occur within the area mapped, has been subjected to strong movements and is greatly folded, but even here the distortion has taken place within the gneisses themselves and does not appear in any marked degree in the larger structures of the overlying limestone.

The nature of the relation between the Kigluaik and Nome groups is in doubt, at least so far as the evidence within the Grand Central area is concerned, because there is uncertainty as to where the dividing line between the two should be placed. As has been explained, the boundary between the two has been drawn on the map so as to include the biotite-staurolite schists in the Kigluaik group; and if this is correct, the field evidence is thought to point toward a relation of conformity rather than one of unconformity.

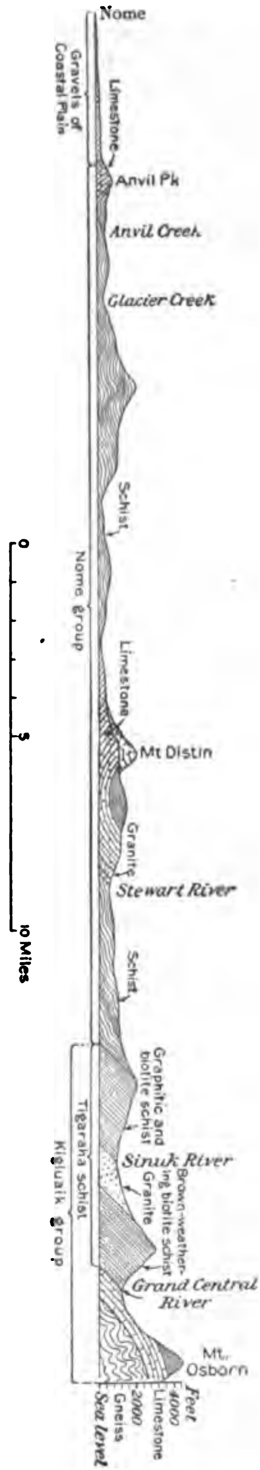


FIGURE 6.—Geologic section, Anvil Peak to Mount Osborn. This figure is diagrammatic and expresses only general relations.

The rocks of the Nome group, more especially the schists, do not present such marked diversity of character or such distinct evidences of bedding as are seen in many unmetamorphosed sediments or in those that are made up of thin beds. Limestones give the best clue to the structure, but even these, on account of their irregularity in distribution and thickness, their interruption along the strike, and their different degrees of alteration or variation in composition, do not furnish sufficient evidence for a solution of many of the problems involved. The difficulties are still further increased by the greenstone intrusions, which, where much metamorphosed, may be confounded with beds of sedimentary origin. Careful field study has led to the conclusion that in general the planes of bedding coincide with the cleavage. This relation does not hold true everywhere, particularly in small close folds, but the exceptions are not apt to lead to misinterpretation of the structure, except in the more massive and highly altered limestone beds. Yet even in these the cleavage commonly agrees with the larger features of bedding. Horizontal cleavage is not uncommon, and cleavage and bedding of low dip—15° to 20°—are the rule rather than the exception.

When the strikes and dips of the various rocks of the Nome group are compared three principal features of the structure are brought out. Throughout a narrow belt from 5 to 6 miles wide bordering the Kigluaik group the strike of the Nome strata is in the main that of the Kigluaik strata—about east-northeast—and the dip is to the south-southeast. The limestone and schist beds forming the south flanks of the Anvil and Newton Peak masses have a west-northwest direction nearly parallel with the coast line and dip toward the north. Throughout the rest of the Nome and Grand Central quadrangles the main structural features have a nearly north-south trend—slightly west of north in the region west of Nome River, north or slightly east of north in much of the region east of Nome River. In a broad way this central part of the area under consideration is characterized by comparatively open folding, but this apparent simplicity of structure is not confirmed when the beds are examined in detail, for closely compressed minor folds are seen in many places. The three features just named suggest that the portion of the Nome group represented on the geologic maps has in general a shallow basinlike structure, the beds dipping at comparatively low angles from the north, west, and south sides toward the central part of the area, the fourth side necessary to complete the basin lying beyond the eastern limit of the quadrangles.

Reference has been made in the outline of the geology to evidences of two periods of folding that have affected the rocks of the Nome group. These evidences consist in the main of two sets of folds that have axes almost at right angles to each other, the one running

north and south and the other east and west. A good example of these folds is seen in the limestone of Newton Peak east of Dry Creek. The limestone beds exposed on the south side of Newton Peak strike east and west and dip north, but when favorable exposures are examined carefully it is found that in many places the rock has been thrown into close minor folds whose axes pitch north and thus lie parallel to the principal dip of the limestone. These minor folds are subordinate, however, to the larger structural features, the principal difference between the two systems as they are seen in this region being that the folds with east-west axes are broad and open, whereas those with north-south axes are intensely compressed and in many places are so small as to be easily distinguished in a small outcrop. Such examples of the two systems of folds as that seen in the limestone of Newton Peak are found in the schists also and in places show the structure even better than at the locality mentioned. It is conceivable that the forces that produced the folds acted simultaneously, but it is believed that the east-west folds are connected with one of the later disturbances that affected the area, probably the intrusion and uplift of the Kigluaik Mountains, and that they were superposed on the folds of an earlier movement. One of the best evidences of this is that the axes of the minor north-south folds pitch in directions parallel to the dip of the east-west folds, a fact which seems to indicate that the north-south folds were produced first. A remarkable peculiarity of the north-south folds is that they were seen only in rocks of the Nome group and were not observed in the Tigaraha schist of the Kigluaik group, in which, if they ever existed, they must have been entirely destroyed by later metamorphism.

Another feature that should be mentioned is that changes from the original condition of the sediments have not taken place uniformly throughout the region. All the rocks have undergone alteration and all are more or less folded, yet neither the degree of metamorphism as expressed by changes in mineral composition of the rock nor the deformation of the beds (folding) is the same in all parts of the area. These differences may be due in part to differences in the original characteristics of the rocks, which led to diverse results when alteration took place. It is probable, however, that they are due in larger part to differences in intensity or in character of the forces that produced the changes. The effects of igneous intrusions are more localized than the changes brought about by mountain-forming movements, and both these agencies have been active in this area.

The rocks of the Nome group were last deformed under comparatively small load—that is, they were subjected to deforming forces while at a slight distance below the surface. The effect of this was that they accommodated themselves to the deformation, not by a re-

arrangement of material within the mass but by rupture and displacement, so that we now find them cut by numerous joints and fault planes. Most of this movement took place after the rocks had already reached an advanced stage of metamorphism and after the principal period of vein formation had been passed.

Displacements and jointing of this kind are perhaps most noticeable in limestone areas. Massive limestone beds show it especially. In many places the rock has the appearance of having been crushed. In one place the blocks have undergone little or no movement on one another; elsewhere they are distinctly faulted. Faulting has taken place in considerable degree throughout the Nome group, yet no general system of faulting was made out. Except in the small faults in which the displacement may be seen, it is rarely possible to tell how great the movement was. This is due to the absence of reference beds, which makes it difficult to correlate outcrops in one locality with those in another.

It was stated at the beginning of this section that the relation between the Kigluaik and Nome groups is somewhat in doubt, but that it appears to be one of conformity, although the possibility of an unconformable relation is admitted. One of the difficulties attending the supposition of conformity is that there seems to be too little space between the limestone south of Salmon Lake and the Tigaraha schist on the north to give room for any such thickness of schist as underlies the limestone of Mount Distin. The solution of this difficulty may be that faulting has taken place along the east-west valley south of the Kigluaik Mountains, giving rise to a displacement within the Nome group, or that there is an unconformity below the limestone that brings about the same result. Both these possibilities were recognized in the field, and evidence to support one or the other was sought without success.

Smith [1] has presented evidence for unconformity at the base of the Sowik limestone in the Solomon and Casadepaga region. The Sowik limestone extends north-northwest from Solomon River near the mouth of Big Hurrah Creek to Kruzgamepa or Pilgrim River, where it turns abruptly to the west along the south side of the Kruzgamepa Valley. Extensive faulting has obscured the relations of this limestone to the limestone south of Salmon Lake, but the field relations suggest their equivalence. If this proves to be the case, there should be, at the base of the limestone in the Nome region also, an unconformity which has not yet been recognized. It is hardly conceivable that sedimentary formations having so great a range in age as those of Seward Peninsula could have been deposited without repeated interruptions and periods of erosion, and it seems certain that if the

[1] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 433, 1910, p. 55.

geology were worked out in detail over the whole area unconformities in deposition might be discovered of which we now have no knowledge.

HISTORICAL GEOLOGY.

The great age of nearly all the rocks of Seward Peninsula, the lack of fossil material in most places, and the exceedingly complicated structure produced by the deformation that the rocks have undergone have made it impossible so far to gain satisfactory knowledge of the geologic history of the region. It is possible, however, from the character of the sediments, the relative position of different formations so far as they are known, and the presence of intruded rocks in the sedimentary beds, to form an idea of the order in which some of the important geologic events took place, even if they can not be assigned to a definite place in the time scale.

It is believed that the first period of sedimentation of which a record remains in the Nome region is that during which the massive limestone in the lower part of the Kigluaik group was laid down. This limestone rests on gneiss, which is most intricately folded and probably is the floor on which the limestone was deposited, although it is not certain that the gneiss may not be a greatly altered igneous mass intruded into the limestone. It has already been stated in discussing the age of the Kigluaik group that there is reason for thinking that the massive limestone of Mount Osborn is one of the oldest sedimentary formations of Seward Peninsula, and that it probably was deposited early in Paleozoic time.

A change in the character of the material deposited by the ancient sea brought about the formation of the argillaceous and quartzitic beds of the Tigaraha schist, which constitutes the upper formation of the Kigluaik group. These schists were intruded by great masses of granitic rock and by sills and dikes of more basic composition. The intrusions took place in several different periods of time, as is shown by their relation to one another and by the different degrees of alteration they have undergone. It is not known that the Kigluaik group was deformed before the sediments of the Nome group were deposited, but there is some reason for believing that it was.

Possibly the Kigluaik rocks were folded and elevated above sea level, so that they underwent erosion before the Nome sediments were laid down upon them, but the resulting unconformity, if it exists, is either not prominent or has been obscured by later deformation affecting both the Kigluaik and Nome groups. Whatever the relation may be, it is believed that the deposition of the Kigluaik sediments was followed by that of the schists and limestones of the Nome group. These deposits were laid down in Paleozoic time and possibly in two or more periods of deposition separated by intervals of

erosion, but of this no definite proof has been found within the area under consideration. Into them were intruded igneous rocks, for the most part dikes or sills of granite and diabase. The available evidence indicates only approximately the time when these intrusions occurred, but as in many places the diabases are entirely recrystallized it is probable that they are not younger than Mesozoic and perhaps are older. There is just as great uncertainty in regard to the granite intrusions, for it is not evident whether they are to be correlated with some of the granite intrusions of the Kigluaik Mountains or are more recent.

After the sediments of the Nome group had been invaded by the basic igneous rocks, or perhaps while these intrusions were in progress, there began the most profound and widespread movement that is known to have affected Seward Peninsula. By it the rocks were folded and given their north-south structural lines and in large measure their cleavage. This folding was accompanied by the deposition of quartz in veins. The greenstone intrusion and the movement that folded the dikes and sills began in post-Silurian, possibly post-Carboniferous time, and although it may have been interrupted during long intervals, was not ended till after the coal deposits and associated beds in the eastern part of the peninsula had been laid down unconformably on the older rocks and folded together with them.[1] The time when these younger sediments were deposited is not definitely known, but they are believed to belong in the upper part of the Cretaceous or possibly in the lower part of the Tertiary. Another dynamic disturbance then began, which gave rise to an uplift along the axis of the Kigluaik and Bendeleben mountains. It was accompanied by granitic and pegmatitic intrusions, possibly also by the deposition of quartz veins in portions of the schists of the Nome group. The relation of the quartz veins to the pegmatitic intrusions, however, has not been definitely established.

Movements of considerable magnitude continued after the granite was intruded and their effects are seen in both groups of metamorphic rocks. These disturbances must have taken place throughout a long period of time, for they have produced a schistose structure in some of the granite and have caused widespread faulting and fracturing throughout the Nome group at a time when the rocks were, it is believed, at or near the surface.

The events so far related may be considered as belonging to the ancient geologic history of Seward Peninsula, and they bring us to the time when the present topographic features began to take their form. These events were scattered through an immense range of time extending from earliest Paleozoic to the beginning of the Ter-

[1] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, p. 25.

tiary, a period vastly greater than has elapsed since then. The records they have left are difficult to interpret, partly because the evidence of many important events is destroyed or undiscovered and partly from failure to understand the full meaning of the records that persist and are known.

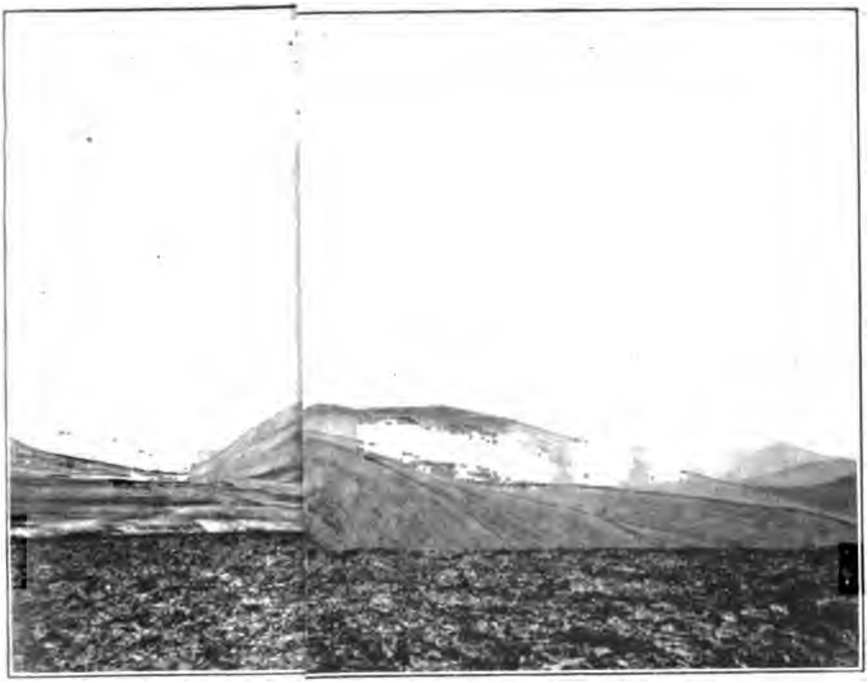
At the time when these earlier events were brought to a close Seward Peninsula was an elevated land mass, on which streams had already begun to carve their valleys. There is reason to believe that this land mass had undergone long-continued erosion, during which whatever rugged features it may have had were removed and its inequalities of elevation were largely reduced. The evidence for this in the Nome region consists in a general accordance of summit levels to a plane sloping gently from the Kigluaik Mountains to the sea.

This land mass was attacked both by streams and by the sea. The rivers deepened and broadened their valleys and carried away the sands and gravel they produced to be scattered over the bottom of the ocean. At the same time the sea was cutting away the cliffs along the coast line and helping to form the rock floor extending back to the foot of the hills 4 miles from the present beach at Nome, on which the coastal-plain gravels were laid down. Changes in the elevation of the land relative to the sea took place. During the formation of the coastal-plain deposits there was a gradual subsidence, which carried the shore line considerably landward of the third beach and must have allowed the sea to enter the lower valleys of Snake and Nome rivers. The amount of this subsidence is uncertain, but it could hardly have been less than 300 or 400 feet. It was followed by a reelevation of the land and a retreat of the shore line to its present position. These movements were interrupted at times and may perhaps have been temporarily reversed, giving way to intervals of relative stability in which the buried beaches of the coastal plain were formed.

The oldest of the coastal-plain gravels give evidence by the fossils they contain of a climate milder than that now prevailing. (See p. 45.) This climate, however, did not continue throughout the time in which the coastal-plain deposits were accumulating, for the later deposits afford proof of glacial conditions existing in the mountains on the north. It therefore appears that a climatic change had taken place which brought about the accumulation of snow and the formation of ice streams that moved down the valleys from the interior highlands toward the coast. Accumulation was greatest in the high mountains of the Kigluaik region, where the ice remained long after it had deserted the lower valleys and where remnants of the former more extensive glaciers remain to the present day. It is in the Kigluaik Mountains that glaciation left its marks most conspicuously on the topography. All the usual evidences of mountain glacia-

tion are found there—cirques, hanging valleys, U-shaped troughs, over-steepened slopes, glacial striæ, rock-basin lakes, and moraines. (See Pls. X and XI.) An excellent example of a rock-basin lake is found in the extreme northwest corner of the Grand Central quadrangle. (See Pl. VI, *B*, p. 14.) It lies in the cirque basin bounded on the south and west by granite walls that rise almost perpendicularly more than 1,000 feet. The open side is choked by morainic débris, but the lake occupies a true rock basin. Other examples might be named. The little basin represented in Plate XII, *B*, was once occupied by a lake, now almost destroyed by the cutting of a channel through the rock rim. To illustrate other glacial features, it may be said that nearly all the tributaries of Grand Central River flow in hanging valleys. Windy Creek and the upper parts of Sinuk and Grand Central rivers occupy typical glaciated U-shaped valleys. Furthermore, the valleys of these three streams contain the largest morainic deposits of the region, but such deposits are recognized in other valleys also, as those of Fox and Thompson creeks and Gold Run. Examples of modified drainage are numerous. Deposition of morainic material has had an important effect on the drainage in many places by damming the streams and producing lakes. Salmon Lake and the two small lakes on Windy Creek and Sinuk River were formed in this way. Over-steepened valley slopes are a common feature of all the larger streams within the high-mountain area. Glacial grooves and striæ, however, are not seen so frequently as the other features noted, because the rock surface, where not covered by gravel and other loose material, is rapidly broken down by frost and the surface markings are thus destroyed.

In that part of the Grand Central quadrangle south of the Salmon Lake and Sinuk River valley and in the Nome quadrangle the evidences of glaciation are less conspicuous yet no less conclusive than in the Kigluaik Mountains. This condition arises from two causes. In the first place, all the evidence so far collected indicates that glaciation was less severe, and in the second place, the ice deserted the valleys of this area long before it ceased to accumulate and began to melt away in the high mountains. There is evidence that ice masses originated in this southern area also. Christian Creek heads in a small lake in a cirque basin once occupied by a small glacier. Such examples are not numerous, however, and there is no doubt that the principal source of ice supply was toward the north. The ice moved southward from the Kigluaik Mountains through the valleys of Silver and Slate creeks into the valley of Stewart River and thence also to the heads of Goldbottom and Grouse creeks, although the principal movement of ice in the Stewart River valley was westward. In the upper part of this valley the ice must have maintained a fairly constant height at about the 800-foot contour for a considerable time, as



GLACIAL CIRQUE ON EAST SIDE OF MOUNT OSBORN.

The lower half of the mountain is gneiss, which is overlain by limestone with interbedded schist or gneiss. A few hundred feet of biotite schist caps the mountain.

A. CHANNEL CUT BY A STREAM FLOWING ALONG THE EDGE OF THE GLACIER THAT FORMERLY OCCUPIED STEWART RIVER VALLEY.

B. SMALL CIRQUE ON SOUTH SIDE OF THOMPSON CREEK VALLEY, 500 FEET ABOVE THE STREAM.

The rock rim across the front ranges in height from 5 to 15 feet but has been cut through by running water.

is shown by the many granite bowlders brought from the Kigluaik area and laid down at this level on the mountain slopes. It is shown also by minor topographic features. One such feature is an abandoned stream channel on the north slope of Mount Distin. (See Pl. XII, *A*.) This channel crosses the axis of the ridge almost at right angles and was formed by a stream that flowed westward along the edge of the ice at the time when the deposits of granite bowlders just mentioned were laid down.

Another great ice stream flowed out through the Grand Central valley. This glacier probably discharged part of its ice into the head of the Nome River valley, although the greater part moved eastward. It originated on the east side of Mount Osborn and appears to have been the largest glacier within the area considered. It formed extensive morainal deposits in the valley below Salmon Lake and thus gave rise to the lake itself, as already noted.

A long glacier moved down the valley of Nome River. It probably received most of its ice from the Kigluaik Mountains, but doubtless acquired further material from small glaciers along its course. This glacier discharged some of its ice into the head of the Stewart River valley and probably spilled over also into the Flambeau and Snake valleys, for erratic granite bowlders are numerous on the divide between Darling and La Spray creeks and in Grub Gulch. It is difficult to determine whether the Nome River glacier extended to the sea. There is no question that part of the coastal-plain deposits contain glacial material, and it seems certain that some of this material was derived from the Kigluaik Mountains. The glaciated limestone and schist bowlders could be of local origin, but this is not true of the granite. Cape Nome is the nearest source of granite material, and although floating ice might be able to distribute granite bowlders from this source over the coastal plain, it would not be capable of placing the granite in the Nome and Snake River valleys. Possibly glacial ice and stream currents together are the causes accounting for the distribution of granite fragments in the Nome coastal plain. There is no evidence at hand suggesting that Seward Peninsula has been subjected to regional glaciation.

So far as present knowledge goes, the belief seems to be warranted that glaciation began after the first of the coastal-plain gravels were laid down, that it reached its maximum long ago, and that it has only recently been ended. Thus there have been at least two changes in the conditions that control glaciation, the first allowing ice to accumulate and the second causing it to disappear. During this time there were at least two principal changes in elevation of the land. Depression carried the shore line back to the slopes of Anvil Peak and the elevation that succeeded this depression advanced the shore line to its present position.

Such changes are trivial in comparison with the long line unknown events that must have taken place during the earlier g logic history of this region. We recognize them because they recent, the evidence of them having not yet been destroyed, but should not fail to remember that they are only a very small par the story. Yet these changes are of great importance in one for they are closely connected with the processes that have r Nome important as a placer-mining district.

ECONOMIC GEOLOGY.

INTRODUCTION.

Nome and the region adjacent to it gained economic import because of their placer-gold deposits. No valuable minerals bes gold have yet been mined there in a commercial way, and no o source of gold than the gravels of the streams and benches and ancient beaches has contributed materially to the great quantity precious metal that made the name of Nome familiar. Prob Nome will always be thought of as a placer region, for even if portant lodes of gold or other metals should be developed there the future the vast quantity of auriferous gravels will be product as long as improvements in methods of mining keep pace with demand for gold; or, to state the matter in a different way, the l of Nome as a gold-placer camp will depend on success in keepi the cost of mining below the recoverable gold content of the grav rather than on the quantity of gravels to be exploited. This sta ment is not made to raise doubt concerning the possibilities of lo mining in this district, but rather to emphasize the importance Nome's placer-gold resources.

The gold production of Seward Peninsula from 1897 to 1911 given in the following table and is represented graphically in figure

Gold and silver production of Seward Peninsula from 1897 to 1911.

Year.	Gold.		Silver.	
	Quantity.	Value.	Quantity.	Value.
	Fine ounces.		*Fine ounces.*	
1897	725	$15,000	65	[illegible]
1898	3,628	75,000	326	[illegible]
1899	135,455	2,800,000	12,190	7,[illegible]
1900	229,790	4,750,000	20,681	12,[illegible]
1901	199,831	4,130,700	17,984	10,[illegible]
1902	220,686	4,561,800	19,861	10,[illegible]
1903	216,032	4,465,600	19,442	10,[illegible]
1904	201,470	4,164,600	18,132	10,[illegible]
1905	232,209	4,800,000	20,898	12,[illegible]
1906	362,827	7,500,000	32,654	21,[illegible]
1907	338,639	7,000,000	20,952	13,[illegible]
1908	247,690	5,120,000	20,477	10,[illegible]
1909	208,118	4,302,000	20,608	10,7[illegible]
1910	170,770	3,530,000	20,317	10,9[illegible]
1911	151,661	3,135,000	17,996	9,7[illegible]
	2,919,531	60,349,700	262,583	152,40[illegible]

The silver is computed from the purity of the gold, the figures given being based on a comparison of assay returns.

It is not possible to give figures that will represent the gold produced at or near Nome separate from that of the whole peninsula, but the output of Nome is so large a proportion of the whole that the form of the curve in figure 7 probably represents with considerable accuracy that for the Nome district alone. The curve brings out clearly some of the important facts in the development of mining there. From the discovery of gold in 1898 there was a rapid rise in production during the first two years, while the rich gravels of Anvil Creek, Snow Gulch, and the present beach were the most important producers. From 1900 production remained relatively constant at a little more than $4,000,000 a year till after the third beach was dis-

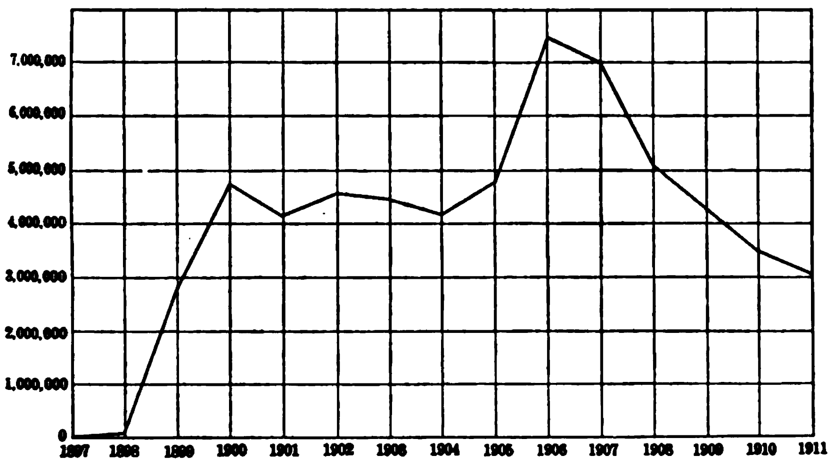


FIGURE 7.—Diagram showing gold production of Seward Peninsula from 1897 to 1911.

covered in 1905, when a rapid rise took place, and a maximum of over $7,000,000 was reached. This high production was maintained for two years, but it was followed by a reduction in gold output, due to the approaching exhaustion of the third-beach placers, and in 1910 the yield fell below the yearly average of the five-year period from 1900 to 1905. Some well-informed mining men at Nome believe that the gold output for 1911 is below the average of what may be expected under present conditions, and that with the installation of new dredges now projected and with continued success on the part of those already in operation an average yearly production of approximately $4,000,000 will be maintained.

HISTORY OF MINING.

A somewhat detailed account of the development of mining on Seward Peninsula has been given by Brooks[1] in a recent publication,

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, pp. 13–39.

and brief statements have been made in earlier reports. It is not necessary to present all the facts anew, but a summary of the important events is desirable here.

Placer gold has been known on Seward Peninsula since about 1865, when the Western Union Telegraph Co. began the construction of a telegraph line to connect the United States with eastern Asia. The route chosen across Seward Peninsula was along Niukluk River to Kruzgamepa River and thence west to Port Clarence and Cape Prince of Wales. Portions of the line were constructed, but the project was finally abandoned because of the successful laying of the Atlantic cable. It is believed that the first white men who had knowledge of placer gold in this part of Alaska were members of parties sent out by the telegraph company to carry on this work. They are said to have found fine gold on Niukluk River.

Gold was mined in the Council region several years before it was known at Nome, and from this vicinity the prospectors set out who made the Nome placers familiar to the world.

Placer gold was discovered on Snake River in 1898 by a party which started from Golofnin Bay to prospect the gravels of Sinuk River. It is said that this party included N. C. Hultberg, J. J. Brynteson, H. L. Blake, and J. L. Haggalin. They worked their way westward along the coast in a small boat, but were storm bound for several days near the present site of Nome and spent the time in prospecting the gravels of Snake River. The results were not encouraging to a majority of the men, and they pushed on to their original destination, but, not having success on Sinuk River, finally returned to Golofnin Bay.

One member of the party, however, Brynteson, was sufficiently impressed with the prospects on Snake River to make another visit to the region. With two companions, Jafet Linderberg and Eric O. Lindblom, he returned to Snake River and on September 20 found rich placers on a stream which they called Anvil Creek from a peculiarly shaped rock on a neighboring hill. They also prospected and located claims on Snow Gulch, Glacier Creek, Rock Creek, and Dry Creek as well as the original claims on Anvil Creek. These streams have since proved to be the greatest producers of the region.

A rush to the region took place immediately after the news reached the miners about Golofnin Bay, and on October 18 the Cape Nome mining precinct was formed and Dr. A. R. Kittleson was elected recorder. It was then too late in the year for mining, but claims on some 7,000 acres were filed by about 40 men.

By the spring of 1899 rumors of the new gold field reached the outside world and started a movement in the Nome direction which progressed during the summer till the population of the camp, then

called Anvil City, was increased to nearly 3,000. A great proportion of this number was composed of disappointed gold seekers from the Yukon country. They found on arriving at Nome that most of the region had already been staked and that their opportunities for sudden wealth were as poor in the new camp as they had been in the camps they had recently left. An attempt was made by them to have all the claims staked up to that time invalidated so as to permit a general restaking of the creeks. This was defeated through the intervention of the military authorities, yet there was scarcely a claim that was not "jumped"—many of them several times.

One of the important events of the season, important not only because it made known a new source of gold to the camp, but because it helped in great measure to relieve the unrest and dissatisfaction felt by the disappointed late comers, was the discovery of gold in the Nome beach. It was free to anyone who had the means to dig up the sand and wash it, and the shore was soon lined with a great crowd, each one at work on his little patch of ground. Although only the most primitive means were employed, over a million dollars was taken out in a period of about two months, and the richest deposits of the beach were practically exhausted.

In this year also the first newspaper was started, a mayor and town council were elected, a post office was established, and a United States commissioner was appointed.

The great rush to Nome took place in 1900. At the end of the previous summer many of the miners returned to the States, and the reports concerning the wealth of Nome were confirmed. A stampede comparable to that of the Klondike set in, and by the middle of the summer probably more than 20,000 persons had been landed on the Nome beach. Jumping of claims and litigation over mining properties continued during the year. One of the most important events was the discovery of deep gravels at the head of Dexter Creek, leading to the beginning of winter mining. Another event having a significant bearing on the future of the region was the construction of a short railroad from Nome to Anvil Creek.

In the following year, 1901, the Miocene ditch was begun. This ditch, the first of the system now bringing water from the upper Nome River to the placer ground near Nome, was originated by two experienced placer miners—W. L. Leland and J. M. Davidson—who were quick to recognize the importance of such a project and lost no time in carrying it out. Important extensions of the ditch were made in 1902 and 1903. The year 1901 also witnessed the installation of the first pumping plants for hydraulic mining.

Hydraulic elevators were introduced in 1903, and since that time improvements in mining methods have consisted chiefly in a reduction of costs by the use of labor-saving machinery.

The third beach, 3 miles north of Nome, was discovered late in the fall of 1904, and although there had been mining on the second beach for two or three years the discovery first turned the attention of most of the mining men toward the possibilities of the Nome tundra, which since that time has held chief place in the minds of the Nome public.

The summer of 1905 at Nome was a season of ditch building and experiment. The Seward ditch and the Pioneer ditch, both taking water from Nome River for use near Nome, were begun. The Wild Goose pipe line, to divert water from the head of Grand Central River to the Nome River valley, was also started. A large dredge was built on Nome River and a steam scraper was installed on the beach.

The most important feature of the winter of 1905–6 was the extension of mining enterprises along the third beach, eastward from Little Creek to a point near Nome River. This was followed in 1906 by the greatest production for a single year that the region has known, and by great activity in prospecting over all parts of the Nome tundra. In 1906 the railroad, which, during the previous year, had been extended to the low saddle north of King Mountain, was pushed forward by way of Nome River and Salmon Lake valley to Lanes Landing, now called Shelton, on Kuzitrin River. Another event of importance in 1906 was the construction of a public road from Nome to the head of Dry Creek, the first road built in the region outside the limits of the city of Nome.

Since 1906 the important events that have taken place include the discovery of several other buried beaches, notably the "intermediate" and "submarine" beaches, and the increased use of dredges in exploiting the coastal-plain gravels. The successful application of dredges to mining in the Nome region is of great importance, for it makes available for working much low-grade gravel from which the gold can not be extracted economically by any other means in use there at present. There were in 1911 nine dredges in the vicinity of Nome.

ECONOMIC CONDITIONS.

Nome is more fortunately situated than most of the other gold-producing camps of Alaska. Its location on the sea gives it great advantage over the interior towns, even those that are reached directly by the Yukon. Six or eight steamships make trips with passengers and freight between Seattle and Nome from the beginning of June until the end of October or the middle of November. A considerable amount of freight also is carried by sailing vessels, one or two of which may be seen at almost any time at anchor off the Nome beach.

The cost of living at Nome in summer is now very little higher than in some of the Pacific coast cities of the United States, and the accommodations are nearly as good.

During the early days little work other than the carrying of supplies was done in winter. The lack of roads and other difficulties of travel made it exceedingly expensive to haul freight in summer, and consequently preparations for mining were made while the snow was on the ground. A great many claims were staked in winter, because traveling was easy and rapid. No prospecting was done, of course, but a man with a sled load of lath or willow sticks could lay claim to more ground in a week's trip than he could hope to stake in a month during the summer. The mining season, or rather the sluicing season, probably did not average over 70 days, although if the days of preparation were added to this the number would be increased to about 90, which is generally given as the length of the working season.

With the discovery of the deep gravels and the beginning of underground mining conditions were much changed. It was no longer necessary for a man to be idle during half or three-quarters of a year, as a force of miners could be kept at work throughout the winter as well as the summer. Winter work is less expensive than summer work. Winter wages usually have been not more than half as great as those of summer, for the supply of labor is larger, there being less work to be done. The gravel mined in winter is piled in a " dump " near the shaft, and is ready for sluicing with the melted snows of early spring, thus further reducing the cost and making it possible to exploit gravels in many places where no other water supply is at hand, or where the cost of ditch water is high.

The transportation of supplies from Nome to the creeks has always been one of the great items of expense in mining. Even on the streams near Nome, such as Anvil and Glacier creeks, the freight charges were high, because until 1906 there was no good road across the tundra, and the railroad practically controlled the freighting. The wagon road to the head of Dry Creek now makes it possible to reach Nome River, at the mouth of Dexter Creek, without great trouble, and from that point northward to the Kigluaik Mountains the river bars furnish good going for freight wagons. Freight charges by wagon to the head of Nome River in 1906 were about $60 a ton. Snake River is less satisfactory for wagons than Nome River, and is more difficult to reach, so that it is not used much as a highway. The Seward Peninsula Railway follows the valley of Anvil Creek to the Dexter Creek divide, and then passes into the Nome River valley. By its extension in 1906 all points in the upper Nome River valley could be reached, but freight rates are not likely to fall appreciably below the cost of freighting by wagon.

A second large item of expense in mining is the cost of fuel. Underground mining made it necessary to have a much greater and better supply of fuel than the region afforded. The gravels are frozen, and must be thawed before they can be removed. Power also is required to hoist them from the shafts. Water must be pumped to keep some of the mines dry, or for sluicing. Coal and oil now furnish heat and power for all mining operations in the Nome region. Attempts were made to utilize the coal resources of Cape Lisburne, but did not meet with success, so that now a large part of the coal burned comes from British Columbia or the Pacific coast of the United States. The price to the consumer averages between $17 and $20 a ton. Crude oil, distillate, and gasoline are employed generally for power. The cost varies greatly and depends largely on freight rates from Nome to the place where it is used.

The question of water supply is of great importance to placer miners. When mining began on Anvil and Glaciers creeks water for sluicing was obtained from the creeks themselves. The drainage areas of the streams are small, and their run-off[1] varies greatly in different parts of the season, so that the supply was uncertain. Thus the amount of gravel that could be handled depended on the summer rainfall, as sluicing did not begin till after most of the snow was melted.

Two methods have been employed to overcome this unfavorable condition. The first and most satisfactory is to bring water from a reliable source and deliver it at an advantageous elevation by ditches. The second, which has not proved economical, is to pump water to the required elevation. There are, as has been said, three large ditches drawing their supply principally from the Kigluaik Mountains that deliver water within a radius of 6 miles of Nome at elevations ranging from 200 to 400 feet above sea level. Besides these there are smaller ditches in several parts of the area that supply water to individual claims.

These ditches removed in some measure the uncertainty regarding water supply, but they are constructed and maintained at a considerable expense. Ice beds on the hill slopes offer one of the greatest obstacles to construction, for the water melts out the ice and undermines the banks. During the first year of use a large amount of water is lost from a ditch by seepage. This difficulty, however, diminishes as the fine sediment in the water fills the cracks and small openings through which the seepage takes place. The critical time for a ditch each year is when the water is first turned into it in the

[1] During the summers of 1906–1909 stream measurements and records of rainfall were made by J. C. Hoyt, F. F. Henshaw, and C. C. Covert. The data collected by them are published in Water-Supply Papers U. S. Geol. Survey Nos. 196 and 218; in Bull. 379, pp. 370–401; and in Bull. 442, pp. 372–418.

spring. Frost loosens the ground and leaves it porous when the thaw comes, so that until the ground settles constant vigilance is necessary to avoid breaks in the embankment. All the large ditches are patrolled regularly throughout the working season.

Water for power, one of the most valuable resources of the region, has not been used up to this time, although two projects for its use have been proposed and may be carried out in the future. One of these contemplates a 50-foot dam across the outlet of Salmon Lake, which would give both greater storage capacity and greater fall than can now be obtained. It is proposed to transmit the power by electric current to those places on the coast that require it.

The purpose of the other project is to generate power by the water of several streams south of Imuruk Basin, on the north side of the Kigluaik Range. Both projects are feasible, and it is perhaps strange that they were not proposed earlier and carried to completion.

Water supply is a function of weather conditions, as are also the length of the working season and in some measure the efficiency of labor.

Abbe[1] places Nome in the Bering seacoast province, one of the eight climatic provinces into which he divides Alaska. It is characterized by temperature ranges and precipitation intermediate between those of the more southern coast provinces and the provinces of the Arctic coast and the interior. He says:[2]

> In the Seward Peninsula, which forms the north shore of Bering Sea, June, July, and August can be counted the summer months. The snow has usually disappeared by the 1st of June and does not begin to fall again till September. In some years June and July are delightfully dry and pleasant months, but the colder rains, which are apt to begin in August and practically continue until snow flies, often accompanied by severe winds, are exceedingly trying. During 1901 the average temperature was 44° in July and August and 40° in September,[3] the number of rainy days during these months aggregating 66. At Port Clarence two years' records[4] showed a mean annual temperature of 22°, with a minimum of −38° and a maximum of 77°. The precipitation of the only year in which a record was kept amounted to 5.58 inches. The ground is usually frozen a foot or two below the surface throughout the year. * * * While the temperatures of the northern Bering Sea coast lines are usually not so low as those of the interior, the greater humidity of the atmosphere makes them harder to resist.

Ice covers Bering Sea in the neighborhood of St. Lawrence Island from early November till the end of April, but does not leave

[1] Abbe, Cleveland, jr., Climate, in Brooks, A. H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 141.

[2] Idem, p. 146.

[3] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 7.

[4] Brooks, A. H., and others, Reconnaissances of the Cape Nome and Norton Bay regions, Alaska: Special publication U. S. Geol. Survey, 1901, p. 163.

the mainland shore till later. In some seasons ice stays on the Nome coast till the last part of May, and even after it has moved away from the beach prevents the approach of boats except those of light draft that can follow the shore line closely.

The growing season for plants in the Nome region is about 100 days or perhaps less, for the late spring frosts end in the later part of May and the early winter frosts come by the middle of September.

A table of the monthly precipitation at Nome from July, 1906, to December, 1910, as given by Henshaw and Parker,[1] is here presented, together with a summary of meteorologic observations covering the period 1907 to 1910, inclusive. A much more extended account of temperature and precipitation at Nome is given in the paper from which this summary is quoted.

Monthly precipitation, in inches, at Nome, Alaska, for 1906 to 1910.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Period.
1906	......	......	......	......	......	......	2.38	2.50	1.02	0.93	0.32	1.91	9.06
1907	2.64	1.46	3.37	0.10	1.12	1.31	2.08	2.68	1.41	.16	.06	.30	16.69
1908	.43	.76	1.19	.02	.19	.90	2.10	2.92	.52	1.13	.26	.75	11.17
1909	.37	.13	.21	45	.15	.88	.82	1.66	.96	1.45	1.16	1.22	9.46
1910	.94	.32	.23	.49	1.03	1.59	3.57	2.61	4.06	1.08	.99	.56	17.47
Mean	1.10	.67	1.25	.26	.62	1.17	2.19	2.47	1.59	.95	.56	.95	13.78

Summary of meterologic observations at Nome, by years, 1907 to 1910, inclusive.

Record.	1907	1908	1909	1910	Mean of period.
Total precipitation, rain and melted snow............inches...	16.69	11.17	9.46	17.47	13.70
Total snowfall...do.....	76.65	62.50	44.25	39.40	55.70
Maximum temperature.............................degrees F..	69	78	70	62	....
Minimum temperature.......................................do.....	−32	−32	−33	−38	....
Mean of daily maximum temperatures ....do.....	30.42	31.55	30.13	28.79	30.22
Mean of daily minimum temperatures ....do.....	17.64	18.88	17.17	15.87	17.40
Mean barometer.......................................inches...	29.86	29.78	29.87	29.82	29.83
Number of clear days..	148	122	163	150	146
Number of partly cloudy days..................................	47	49	55	40	48
Number of cloudy days..	170	195	147	175	172
Number of days with rain or snow............................	103	84	70	114	93

The Nome and Grand Central quadrangles contain no timber. There are willows along the streams and scattered clumps of alders on hill slopes, but spruce does not extend west of Niukluk River—that is, not within 25 or 30 miles of the eastern boundary of the quadrangles. (See fig. 8.) Some species of willow in this district attain a thickness of 4 inches and a height of 15 to 20 feet. Trees of such size are not numerous and probably require the most favorable con-

[1] Henshaw, F. F., and Parker, G. L., Surface water supply of Seward Peninsula, Alaska: Water-Supply Paper U. S. Geol. Survey No. 314, 1913, p. 28.

ditions for growth. Most of the willows seen along the stream courses do not exceed the height of a man nor have a greater thickness than about 2 inches, yet they have made it possible to prospect many parts of Seward Peninsula where no other fuel is to be found. In the early days at Nome driftwood from the beach served as firewood and even as material for cabins, but no such source of supply was available to the miners on the creeks. At present all fuel (coal and oil) is shipped to Nome from outside points.

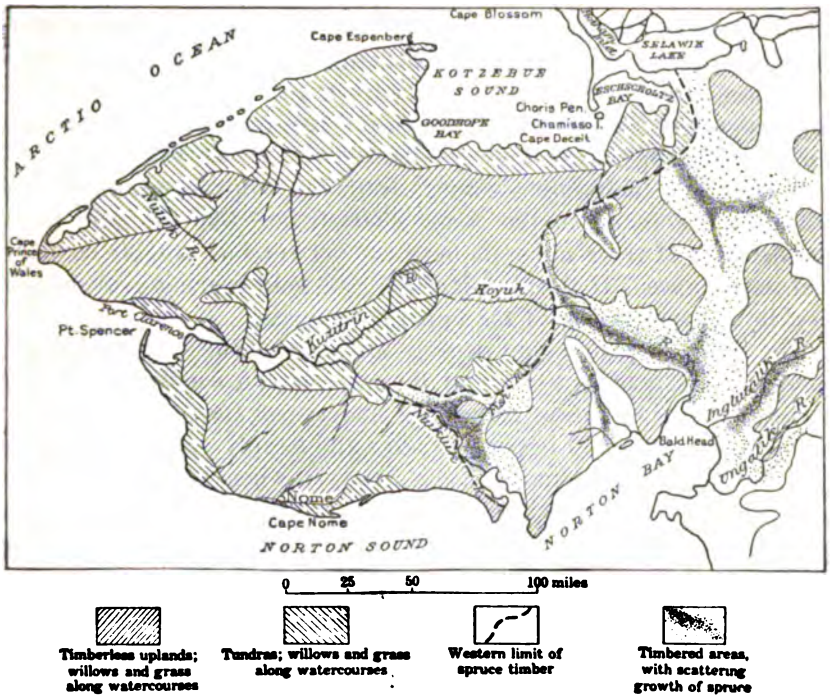


FIGURE 8.—Map showing distribution of vegetation on Seward Peninsula.

The Nome district, except the higher hilltops, is covered for the most part with a mat of vegetation, made up chiefly of various kinds of moss, but including a great variety of small plants and in places dwarf willow, dwarf birch, and grasses of several kinds. This vegetation has formed many deposits of peat, some of which have been used as fuel. The peat is cut into blocks and stacked to dry for a considerable time before it is burned; and although the proportion of ash is great, very satisfactory results are reported.

Grass is plentiful on most of the lower slopes of the hills and valleys. It serves as food for horses, but must be supplemented by grain or hay when the animals are doing heavy work.

MINERAL RESOURCES.

METALLIFEROUS DEPOSITS.

It has been stated herein that the mineral wealth of the Nome district, so far as present development shows, lies in its deposits of placer gold. Many gold-bearing veins and mineralized zones cutting the schist bedrock have been discovered, and on several of them development work has been conducted for a number of years. The results, when compared with the great production of the gold-bearing gravels, are disappointing, yet the very rich placers of Anvil Creek, Dexter Creek, Snow Gulch, and the beaches derived their gold from a near-by source; and although the original deposits may have been widely disseminated in bedrock and became valuable only after repeated concentration, the placers furnish reasonable grounds for the hope that lodes may be discovered. Other valuable metals and minerals, including bismuth, antimony, copper, graphite, and scheelite, are found in the Nome district, but, like the gold lodes, the deposits of these minerals have not yet reached notable commercial importance. It thus appears that the gold-bearing gravels rank first in a consideration of the mineral resources.

The study of placer-gold deposits involves a study of the bedrock source of the gold as well as of the manner and conditions of their occurrence. When these things are understood they serve as guides in the search for gold-bearing gravels and supply valuable information for the exploitation of such deposits when found. It would thus seem proper to consider the bedrock source of gold before taking up the placer deposits, but because of their present far greater commercial importance the placers are described first.

PLACER DEPOSITS.

KINDS OF PLACERS.

A description of the Nome placers at this time, long after most of the observations were made, necessarily deals with many things that are now only history to the men who have been active in developing the field. The richest deposits of some of the creeks and benches and even of the third beach are nearing exhaustion. Other bonanzas have not been found to take their places, and only by the use of new and better methods of mining is the present production maintained.

It is fully recognized that the following descriptions of placers lack much to make them complete and that the critical reader will find occasion to raise questions, yet it is worth while to assemble in one place the records of observations, most of which have already been published,[1] although they are not new nor exhaustive, for they

[1] Accounts of placer mining at Nome since 1905 will be found in the several volumes of Mineral resources of Alaska, Bull. U. S. Geol. Survey No. 284, 1906, pp. 132–144; No. 314, 1907, pp. 126–145; No. 345, 1908, pp. 206–216; No. 379, 1909, pp. 267–283; No. 442, 1910, pp. 353–359; No. 480, 1911, pp. 40, 52; No. 520, 1912, pp. 339–344; also in Bull. '8, 1908.

thus become conveniently available for the use of the thoughtful prospector as well as the geologist. The writer's own observations have been supplemented by those of earlier and later workers in the field, particularly Smith and Henshaw, both of whom collected data on the Nome placers during the course of other work. An excellent paper by T. M. Gibson[1] on the Nome beaches should be read by all those interested in this subject.

The principal placers of the Nome vicinity may be grouped under the four following heads, which are not intended to represent a classification of gold placers but are used mainly for convenience in description: 1, Residual placers; 2, stream placers; 3, bench placers; and 4, beach placers.

These headings are descriptive and refer only secondarily to the origin of the deposits. As a further help in description and to avoid confusion, the placers are here grouped according to the drainage systems of which they are members.

RESIDUAL PLACERS.

Origin.—Residual placers are produced by the decay of gold-bearing rock and the removal by solution or by water and wind transportation of the lighter products of decomposition, the heavier minerals remaining in a natural concentrate. The process is common and is of economic importance where the residual minerals are valuable and occur in sufficient amount to return a profit in mining.

Such concentrated minerals, when compared with those found in streams or on the beach, are seen to have moved relatively short distances from their original bedrock positions, and the movement may be considered as downward rather than horizontal. It is evident that accumulations of this kind are favored by very long continued weathering and are the result of subaerial rather than of stream activities. Gold placers, in which the accumulated gold represents residual material, are known at a number of localities, and some of them have been mined with profit.

Rock Creek.—Gold occurring as a residual concentration is found on the hill slope between Rock and Lindblom creeks. The bedrock is schist, cut by many small veins and stringers of quartz in which pyrite is abundant. These stringers also carry gold. The slope of the hill is gentle, and an accumulation of débris consisting chiefly of angular schist and quartz fragments and ranging in depth from 3 to 6 feet is present. Without doubt a considerable portion of this débris came from the upper slopes of the hill, for its character indicates that it has not traveled far. The gold occurs near and on bed-

[1] Gibson, T. M., Pay streaks at Nome: Min. and Sci. Press, vol. 102, 1911, pp. 424–427, 462–467.

rock and is associated with a great deal of iron-stained quartz and with schist equally or more stained. Sluicing is attended with some difficulties, chief among which is that of obtaining water, so that mining has been carried on only on a small scale and the production is not large. Attempts have been made to exploit the bedrock source of the gold, but with what success is not known to the writer.

A peculiar association of minerals, including the sulphides of lead, antimony, arsenic, and a little copper is found here, and for a time was thought to be possibly a new mineral.

Pioneer Gulch.—Residual gold deposits are mined at Pioneer Gulch, on the west side of Snake River just below the forks. The deposits here occur near a small gulch on a hill slope much steeper than that of the Rock Creek locality just described. The bedrock is schist, cut by small veins of quartz containing iron pyrite, and stained with the oxide resulting from decomposition of the pyrite. Neither the veining nor the mineralization is as notable here as at Rock Creek.

Part of the gold and of the fragmental material, although it is not rounded nor waterworn, has probably moved some distance down the slopes, but some of it appears to be almost in place. Gold may be seen free and in some of the quartz fragments. The free gold is coarse and angular.

Water for operating a hydraulic plant is provided by a ditch having its intake at the mouth of Waterfall Creek and drawing an additional supply from Dewey Creek and Surprise Gulch.

Boer Creek.—Boer Creek is a small southern tributary of Hudson Creek, which joins Buffalo Creek near the head of Nome River. It flows in a steep, narrow valley cut chiefly in black graphitic schist in which are a few interstratified limestone beds. There is little gravel in the creek, but a small hydraulic plant near its mouth is operated for recovering gold from the decomposed graphitic schists, from which nearly all the gold present appears to come. These schists are silicious and thinly laminated. Near them is a dark-blue limestone.

Nekula Gulch.—A claim on Nekula Gulch, commonly known as "Caribou Bill's claim," probably lies near the border line between residual deposits and stream deposits. The gravels were of extraordinary richness and occupied a great hole in limestone. The gold evidently must have traveled more or less to reach its resting place, but its condition indicated that the movement had not been great. This deposit may be compared with some of the rich potholes in limestone on Ophir Creek, in the Council district, and will be described more fully in the account of stream placers on Nekula Gulch. (See pp. 83–84.)

STREAM PLACERS.

PRINCIPAL CLASSES.

Stream placers in the Nome region are of two kinds. Most important are those whose gold seems to be a first concentration resulting from weathering of gold-bearing rock and accumulation of the gold in the channels of streams that carry away the products of weathering. To placer deposits of this nature belong the greatest number of the stream concentrations.

The second kind of stream placers comprises those whose gold is concentrated from gravels of a previous period of deposition. Such placers are well represented on those streams that arise within the coastal plain and on the lower portions of streams that cross the coastal plain. The gold of this concentration is not derived directly from the bedrock source but from a supply disseminated throughout the gravels in which the stream is cutting.

A common variation of stream placer deposits is found in the gold-bearing sands and gravels of river bars, but such placers have no importance yet in the Nome region, although the bars of Nome and Snake rivers are known to carry a small amount of gold.

The most important and productive stream placers of the Nome area were found on Anvil Creek, Glacier Creek and its tributary Snow Gulch, Dexter Creek with its tributary gulches (especially Grass Gulch), and Dry Creek. (See fig. 9.) With these may also be named Bourbon Creek, Newton Gulch, and Hastings, Osborn, and Dorothy creeks. A considerable number of smaller streams complete the list of creek placers of the region, for neither Nome River nor Snake River has reached importance as a gold producer. The writer is indebted to the reports of Brooks and to the notes and unpublished manuscripts of Collier for a large part of the data on the stream placers, collected prior to the year 1905. This material has been incorporated with the results of observations made during the two years in which the field work for this report was carried on.

SNAKE RIVER BASIN.

Snake River.—Snake River heads in the region adjacent to Mount Distin, but the name Snake is applied only to the lower part of the stream beginning at a point 15 miles from the coast. The length of this lower part is much greater than 15 miles, however, for the river follows a winding course through a broad valley in the upland region, and, after crossing the coastal plain to a point within about a mile of the coast, turns abruptly eastward and flows nearly parallel with the shore for about 5 miles before joining the sea. Its elevation

at the mouth of the North Fork is 170 feet, giving a gradient of not over 7 or 8 feet to the mile.

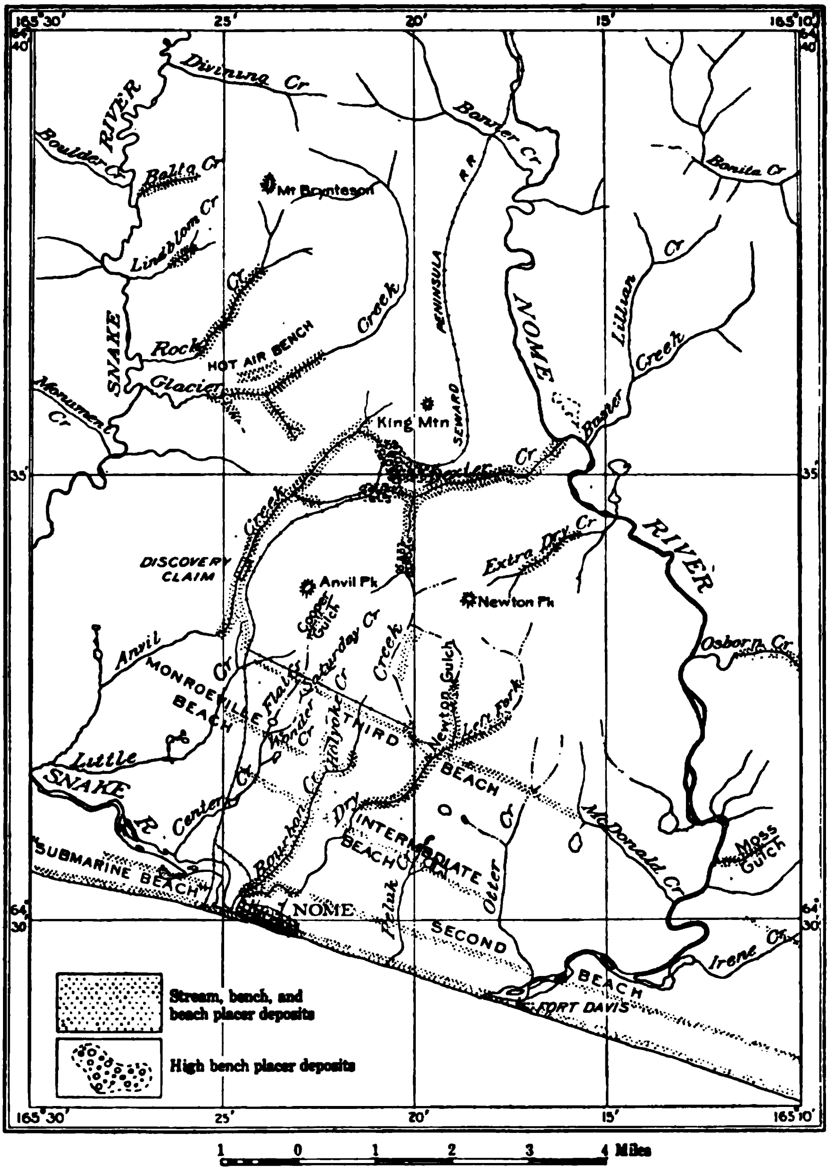


FIGURE 9.—Sketch map of the vicinity of Nome, showing distribution of placers.

Low marshy ground borders the river and forms a valley floor whose width varies between half a mile and 1 mile, and from which the lower hill slopes rise gently on either side. The river swings back and forth across this low land in a succession of meanders, whose complexity suggested the name Snake to the first prospectors.

The Snake River valley has a deep gravel filling, but has been very little prospected. Gold is found on some of the bars. The deposits, however, are not rich enough to pay for working on a small scale and offer little encouragement to prospectors.

The Snake River basin, however, includes some of the richest creeks of the Nome region, such as Anvil, Glacier, and Dry creeks, and other less important streams.

Anvil Creek.—Anvil Creek is the most widely known stream of the Nome region, both because it is the stream on which the first great discovery was made and because of its gold production, which during the first five years of mining amounted to $1,000,000 a year.

Anvil Creek is nearly 6 miles long. The lower 2 miles lies within the coastal plain, but the upper part flows through a broad valley in the upland plateau. About 3 miles of the stream has been productive. This part extends from the vicinity of Moonlight Springs to Nekula Gulch.

Moonlight Springs has an elevation of 100 feet above sea level. The elevation of Nekula Gulch at its mouth is almost 400 feet, so that Anvil Creek between these points has an average grade of very nearly 100 feet to a mile. The drainage basin is small, and scarcity of water for sluicing was frequent in the early days.

Anvil Creek flows in a valley whose rocks are chiefly chloritic and graphitic schist of the Nome group. In the vicinity of Discovery claim, which is situated near the point where the creek leaves the hills to cross the tundra, the bedrock for about half a mile is black graphitic schist. Above that for another half mile is chloritic schist and beyond comes a succession of chloritic and graphitic schist beds, some of which are calcareous. Many of these schist beds are faulted and in places, as near Discovery claim, show small veins and stringers of quartz with pyrite.

Anvil Creek cut its present channel into the schist of the valley floor and is confined on the east by an escarpment not over 15 to 20 feet high in most places. A low bench, with surface sloping gently toward the stream, is thus formed along the east side of the valley. It does not appear on the west side, however, for the creek flows close to the valley's western slope, which here rises rather steeply. The flood plain has a width of approximately 300 feet at the lower end of the productive part of the creek and narrows gradually toward the mouth.

Gold-bearing gravels were first found along the present stream channel and later on the rock bench east of the creek. The gravels of Anvil Creek consist chiefly of material like the rocks of the surrounding hills, and are doubtless derived in large part from sources within the drainage area of the creek, yet rounded granite bowlders from the size of cobblestones up to 2 feet or more in diameter are

found in the valley, especially along its east side, and it is, therefo evident that the surficial deposits are not entirely of local origin.

Gravel deposits ranging from 3 to 5 feet in thickness have been posed all along the present channel by mining operations. The s face deposits on the bench east of the creek reach a thickness of feet, but the thickness is much more irregular there than along creek, as the bench gravels have been partly eroded and in one or places persist only as isolated patches.

All the claims from the tundra to Nekula Gulch have yielde profit. Some were far richer than others, for the gold is not eve distributed throughout the length of the creek. Discovery cla together with the ground above and below for a short dista proved to be the most valuable part of the creek. The richer posits of the present channel were in part a secondary concentrat of material brought by Anvil Creek and tributary streams from th places where they attacked the auriferous gravels of the bench on east and especially where they cut into the gold-bearing gravels

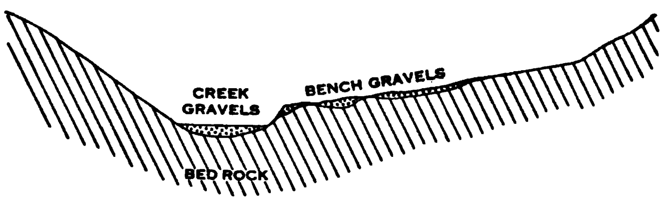


FIGURE 10.—Diagrammatic section of Anvil Creek valley, showing bench gravels.

an old channel of Anvil Creek. In a larger way the great differe in concentration between the auriferous gravels of the upper e of Anvil Creek in the vicinity of Nekula and the gravels found 2 3 miles below, near Discovery claim, appears to depend on a diff ence in gold content of the rocks from which the placers were rived. Collier[1] says on this subject:

> The rich placers on the upper part of the creek, for example, can be tributed partly to the reconcentration of high bench gravels washed down Nekula Gulch, and the richness of the placers near Discovery claim is in probability due to veins in the local bedrock, for it is there that all the p nomenally large nuggets have been found, and these could not have been tra ported far. The facts necessary for estimating with any degree of exactness t gold tenor in the Anvil Creek placers are not at hand, but the average for the gravels mined along the creek can not have been less than $5 a cubic ya In the richer spots much of the gravel contained more than $50 to the cubi yard.

The gold-bearing gravels on the bench east of the creek (fig. 10 are found chiefly in well-defined channels cut in bedrock by Anvi Creek and its tributaries at a much earlier stage of their history, bu

[1] Collier, A. J., The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geo Survey No. 328, 1908, p. 188.

the auriferous deposits are not confined entirely to these channels, as in a number of localities they extend beyond the channel rim. The channels are not indicated by the topography, and their presence was not known till mining began on the bench gravels. What seems to be the principal old channel lies at a distance of 300 to 600 feet east of the present stream and although not exposed continuously can be traced with a considerable degree of certainty from a point about a mile above Specimen Gulch as far south as Discovery claim. Its greatest width so far as known is about 120 feet, and at one place it has a depth of 20 feet. It has been cut by tributaries of the present stream, and its rim is in some places destroyed on one side. A short distance above Specimen Gulch the main channel lies about 400 feet east of Anvil Creek. Between it and the creek a smaller rock-cut channel was exposed in mining. It is about 20 feet wide, is 12 feet deep, and where exposed has the form of a letter S.

From observations in the workings on the bench it is seen that there is no uniformity in the character of the gravels present. Fifteen feet of gravel is exposed in an old channel half a mile above Specimen Gulch. The channel is here 60 feet wide and lies from 200 to 300 feet east of the creek.

Just north of Specimen Gulch a channel 70 to 120 feet wide was exposed in a pit 20 feet deep and 200 feet long. The east rim is steep, but the west rim has a gentle slope. A graphitic schist bedrock is overlain by 7 feet of auriferous gravel, which in turn is covered by 12 feet of sandy clay. Pebbles and bowlders of schist, greenstone, and a few of granite are seen in the clay.

At Specimen Gulch where it intersects the old channel the following section was exposed:

Section in old channel at Specimen Gulch.

	Feet.
Moss and muck	1
Coarse gravel	8
Clay	1
Bedrock, graphitic schist.	

Half a mile below Specimen Gulch not less than 500 feet of the main channel was uncovered, also a small tributary channel about 7 feet deep and 8 feet wide entering from the west. The section showed the following beds:

Section in old channel half a mile below Specimen Gulch.

	Ft.	in.
Light-brown sand and angular gravel	6	
Brown clay		1
Gravel with large bowlders, mostly flat, some measuring 18 inches in longer dimension, but most of those at the bottom of the bed much smaller	15–20	
Schist bedrock.		

About a mile above Discovery claim the old channel was exposed. It is bounded along most of its length by well-marked rock rims but is smaller than the present channel of the creek and about 20 feet higher. There appear to be a number of channels rather than a single one. At the south end the working faces show:

Section in old channel 1 mile above Discovery claim.

	Feet.
Brown clay and soil containing a few angular pebbles	3
Fine gravel with sticky clay sediment	6
Coarse gravel, flat, 4 to 6 inches across, and sand	3
Bedrock not exposed.	

Gold is distributed through the 9 feet of gravel, both in the upper 6 feet of fine clayey material and in the underlying coarse gravel and sand.

About three-fourths of a mile above Discovery claim a remnant of the old channel deposits was discovered 300 feet east of the escarpment and 50 feet above the creek. It occupied a depression bounded by rock walls and was only about 100 feet long, but the gravel was very rich.

The rock bench on the east side of Discovery claim stands about 10 feet above the creek at its lower edge and slopes gently for 500 or 600 feet to the foot of Anvil Mountain. Gold-bearing gravel of unusual richness was discovered on this bench. Its thickness ranged from 4 inches to 4 or 5 feet, and as in most other places the greatest concentration of gold was in its lower part. Gold was present also in the bedrock beneath. The gravel was overlain by 12 to 14 feet of yellowish clay, which contrasts sharply with the more usual covering of about 3 feet of peaty "muck." The bedrock at this place is graphitic schist with an irregular surface but is not cut by any well-defined channel. One of the old channels of Anvil Creek, however, extends south from Discovery claim in this vicinity to Little Creek, where it was at first mistaken for the "third beach." This channel, according to Gibson,[1] is incised into the schist bedrock to a depth ranging from about 4 feet to 12 feet. It has been buried in delta and beach deposits, and the auriferous gravels, besides filling the channel, overflowed its rims both to the east and to the west. Near the old shore line the gravel was mined to a width of 500 or 600 feet, although the channel itself was not more than 150 feet wide. The gravel ranged from 20 to 25 feet in total depth and was overlain by 12 to 15 feet of ice, "muck," and surface vegetation. Coarse creek wash, quartz, schist, and limestone filled the channel depression in bedrock. This material was overlain by cross-bedded delta and beach deposits of similar composition and character, but including also a small amount of interbedded beach-worn pebbles and sand.

[1] Gibson, T. M., Pay streaks at Nome: Min. and Sci. Press, vol. 102, 1911, p. 464.

As has been stated, bench gravel containing sufficient gold to yield a profit on mining is not confined to the old channels of Anvil Creek. In many places the gold-bearing deposits extend beyond the channel rims, especially the western rim, and spread out upon the bench below. Many of the Anvil Creek claims have been worked over twice, and one or two have been worked three times. All the gravel is put through the sluice boxes, and from 6 to 18 inches of the bedrock is broken up with the pick and washed. The gold is now nearly exhausted on the present channel floor, but work is still carried on in a number of places, and on the bench much gravel remains that with cheaper methods of mining will yield a profit.

Anvil Creek gold as a rule is chunky rather than flat. Two nuggets worth approximately $1,500 and $1,700 were found on Discovery claim, and a third nugget, the largest ever brought from Alaska, was discovered on the bench east of Discovery claim. This nugget with its contained quartz weighed 182 ounces. The gold in it was calculated to be worth $2,660. Many smaller nuggets were found, and pieces worth several dollars were common.

The richest gravel of Anvil Creek was that on Discovery claim and in its vicinity, where also the coarsest gold was found. From that locality the average size of the placer gold decreased downstream, as would be expected, for the lighter particles would be transported farther by the water, and probably the particles that traveled far were more or less reduced by abrasion.

With the gold were concentrated a number of heavy minerals, of which magnetite, garnet, and scheelite are most common. These minerals, however, do not cause great difficulty in cleaning the gold. Dr. Cabel Whitehead, formerly of the Alaska Bank & Safe Deposit Co., at Nome, has given the fineness of Anvil gold as 0.89, or $18.33 an ounce. The Anvil Creek placers have averaged probably not less than $5 to $6 to the yard of gravel and locally have yielded 10 times that amount.

Specimen and Nekula gulches.—Two small tributaries of Anvil Creek, Specimen and Nekula gulches, may be described in connection with it. Nekula Gulch is one-third of a mile long and heads near the saddle at Dexter station. The bedrock is graphitic and chloritic schist, calcareous schist, and limestone. The stream gravel averages about 3 feet in thickness and consists of schist, quartz, and some limestone. The gold in this gravel is largely or perhaps wholly derived by secondary concentration from the high-bench deposits near Dexter station.

A short distance north of Nekula Gulch and about 50 feet lower than the saddle between it and Deer Gulch very rich gravels, previously referred to as "Caribou Bill's claim," were discovered in a hole, which seems to be a cavern or sink in the limestone bedrock. The pit

made in the gravel was about 30 by 50 feet in area and 20 feet deep. This auriferous deposit was probably a part of the high-bench deposit and has been described as such by Collier. Calcareous schist inclosing a bed of limestone forms the country rock. The sink, if such it is, was shown by a shaft to have a depth of nearly 90 feet. It is filled with gravel consisting of rounded schist fragments and limestone in yellow clay probably carried into it by running water. The gold mined here was coarse and angular and appeared to have traveled only a short distance from its bedrock source. The gravel was remarkably rich; its gold content has been estimated as not far from $1,000 a cubic yard.

Auriferous gravel was found below this claim on Nekula Gulch, but none had so high a value as the deposit just described. Most of the gravel was shallow, averaging about 3 feet deep. The gold was most concentrated on bedrock and is reported to have reached about $1.50 to the yard.

Specimen Gulch heads near the high-bench gravels between Anvil Creek and Grass Gulch and, like Nekula Gulch, received some of its gold from these older deposits. At its lower end part of its gold was doubtless received from the bench deposits east of Anvil Creek. The bedrock is graphitic schist. The gravel has a thickness of 8 feet on the Anvil bench and reaches 10 feet in other places. Near the old Anvil channel the gravel rests on 1 foot of clay, and here the best pay was found. The gold does not show much wear and probably has not traveled far.

Glacier Creek.—Glacier Creek is another of the streams staked by the discoverers of the Nome placer field. It has a length of 5½ miles and joins Snake River 6½ miles north of the coast. The upper 4 miles of Glacier Creek lies in a broad upland valley with gently sloping sides, but the lower part crosses the lowland of Snake River, into whose gravels it has intrenched its bed. The productive part of the stream extends from a point just below the mouth of Bonanza Gulch to Snow Gulch. Some mining, however, has been carried on above and below these points. From Snake River to Bonanza Gulch the grade of the creek averages 50 feet to the mile. This stretch includes that part of the stream crossing the Snake River lowland, which is the part of least grade. Above Bonanza Gulch the grade increases to 75 feet to the mile.

Most of the gold of Glacier Creek has been taken from four localities, the bed of the stream from Snow Gulch down to the Snake River flats, Snow Gulch, Hot Air bench north of the most productive portion of the main stream, and Bonanza Gulch.

Glacier Creek above Bonanza Gulch flows through a rock-walled channel from 100 to 300 feet wide, incised in schist belonging to the Nome group. The bedrock consists, for the most part, of chloritic

schist, in which are local limestone beds. The schist in a number of places carries a considerable percentage of pyrite and is cut by veins of quartz containing pyrite and a small amount of gold. One selected specimen of such vein material assayed half an ounce of gold to the ton.

Below Bonanza Gulch the flood plain of Glacier Creek has a width of 200 to 500 feet. Prospect holes have been dug along the lower part of the creek, and the gravels there are known to carry gold, although, on account of the small content of metal and the low grade of the creek, little effort has been made to recover it. The test pits show a depth of gravel ranging from 5 to 20 feet. One mile above the mouth (whose elevation is 40 feet above sea level) a section showed 10 to 12 feet of gravel resting on schist bedrock and overlain by 2 to 3 feet of muck. The gravel carries fine bright gold that has evidently traveled a considerable distance.

Near the mouth of Snow Gulch 6 feet of gravel, made up of schist and quartz, rested on schist bedrock. The lower third of this gravel carried considerable gold.

Little mining has been done on Glacier Creek above the mouth of Snow Gulch, and most of the operations on the creek proper have been confined to the part between Bonanza and Snow gulches. Most of the gold is fine and worn. Garnet and scheelite accompany it.

Snow Gulch.—Snow Gulch was formed by a small stream about three-quarters of a mile long, heading in the divide between Anvil and Glacier creeks. The stream flows directly across the bedding and cleavage of the schist, whose upturned edges form the riffles that caught the gold. In its lower and less steep portion this gulch has a grade of 150 feet to the mile, but the upper quarter mile has a much steeper grade. The bedrock is schist, in which are a few limestone beds, some reaching 12 feet in thickness. Faults are numerous, and the rocks are cut by many small quartz veins. Veins of quartz and of calcite carrying free gold are seen on the ridge at the head of the gulch. Owing to the steep grade of the stream, deep gravels did not accumulate. The deposits averaged 3 or 4 feet in depth near the lower end, but the gulch is now swept almost clean by mining operations, and the gold supply is exhausted. Considering its size, Snow Gulch was one of the richest streams discovered in the Nome region, more than a million dollars' worth of gold having been taken from it. Most of the gold was fine and rounded, but it is not believed to have traveled a great distance; part of it, at least, was probably derived from gold-bearing veins in the immediate vicinity.

Hot Air bench.—Northwest of the mouth of Snow Gulch, nearly 100 feet above Glacier Creek, auriferous gravels were found along an old channel once occupied by the creek. The north rim of the Glacier Creek channel rises in a steep bank that limits a southward-

sloping bench on which the old channel gravel lies. There was no topographic indication of the presence of a channel, but mining operations disclosed one. It is cut in the schist bedrock and extends nearly parallel with Glacier Creek for 400 feet or more. Its east end turns toward the creek, but its west end is less well defined. The channel has a depth of approximately 20 feet and a width of 100 feet. Both rims are seen except in one or two places. Schist forms the bedrock and is cut by quartz veins, which opposite the mouth of Snow Gulch reach a thickness of 6 inches and carry considerable pyrite. Pyrite is abundant also in the schist itself. A section of the surface deposits included 4 to 5 feet of vegetable matter and clay overlying the same thickness of gravel, which rested on the schist bedrock. Schist and quartz with some limestone and a few granite pebbles compose the gravel. It is estimated that the pay streak carried nearly $50 in gold to the cubic yard. The gold is believed to have been derived from the mineralized schist and quartz veins found in the immediate vicinity.

Bonanza Gulch.—Bonanza Gulch is a shallow depression, less than half a mile long, on the hillside south of Glacier Creek. It joins Glacier Creek where that stream leaves the upland valley to cross the Snake River lowland. A small stream flows in this depression, but except in spring does not carry enough water for use in mining. The bedrock is highly folded and much-decomposed schist. At the lower end of the gulch 2½ feet of gold-bearing gravel was overlain by 5 to 6 feet of sandy clay and 1 foot of surface "muck" containing much vegetable matter. The gold was fine and worn by travel. All the richest gravels so far as known have been mined out.

Rock Creek.—Rock Creek is a small stream, which rises on the south slope of Mount Brynteson and joins Snake River about half a mile above Glacier Creek. The productive part of the stream extends from a point 1 mile above Snake River to a point nearly half a mile farther up the creek. Rock Creek flows in a channel 25 to 30 feet deep cut in bedrock consisting of schist with some limestone beds. Many small quartz veins are present.

The gravel deposit averages about 5 feet in depth, and ranges in width from 50 to 100 feet, according to the width of the rock channel. A few nuggets have been found, but most of the gold is rather fine, and is recovered by the use of mercury. Associated with the gold are considerable scheelite and less magnetite, limonite, and garnet. A vein of scheelite 3 to 4 inches wide is reported to have been uncovered on the creek.

Lindblom Creek.—Lindblom Creek is about 1 mile long and flows down the west slope of Mount Brynteson. It has cut a narrow gulch in the schist of the mountain and for part of its length flows in the gravel floor of Snake River. The gravel is shallow, and only a

small amount of gold has been found in it. Little mining has been done there.

Balto Creek.—Balto Creek joins Snake River directly west of the summit of Mount Brynteson. It flows in a narrow gulch cut in the schist. A small quantity of gold was obtained from its shallow gravels.

Boulder Creek.—Boulder Creek has produced a small amount of gold, but its productive portion lies outside of the area under consideration.

Bangor Creek.—Bangor Creek joins Snake River near the southern boundary of the Grand Central quadrangle, but only 3 miles of it is represented on the map. It flows in a narrow V-shaped valley and through most of its course has a grade of nearly 90 feet to the mile. The bedrock is schist, with which a few limestone beds are interstratified. The gravel consists chiefly of schist and quartz. Many large bowlders of quartz, also bowlders of granite, are seen in the stream. A hole 11 feet deep was sunk at the mouth of Bangor Creek without reaching bedrock, and another near by on Snake River was put down 22 feet with the same result.

Mining has been carried on near the mouth of Butterfield Canyon. The gravel here has a depth of 14 feet and is said to yield $2.50 to the cubic yard. The gold is fine, but nuggets worth $15 or $20 are found. Scheelite and hematite occur with the gold. Pieces of scheelite weighing half a pound have been found in the concentrates.

Last Chance Creek.—Last Chance Creek, a small tributary of the North Fork of Snake River, flows in a deep, narrow valley and supplies sufficient water for such mining operations as have been carried on. The bedrock is chloritic schist in which are graphitic and calcareous beds. Limestone beds are not uncommon. These same rocks supplied material for the stream gravel.

A small amount of gold has been found, but mining was not very profitable. Just above Dewey Creek the heavy concentrates from the gravel contained, besides the gold, scheelite, hematite, magnetite, and pyrite. The gold was rough and iron stained. Nuggets worth $2 were found.

Goldbottom Creek.—Goldbottom Creek flows around the west and south slopes of Mount Distin. Its bedrock is partly schist and partly limestone, and its gravel consists of the same materials, but a considerable quantity of granite bowlders appears along the stream, especially near its mouth. The stream has produced a small amount of gold, most of which was obtained by pick and shovel. A small hydraulic plant was set up, on the upper part of the creek in 1905, but whether the undertaking was profitable or not was not learned. Stream tin is found in the gravel at a number of places along the creek.

Steep Creek.—Steep Creek, a small tributary of Goldbottom Creek, has had a small gold production for a number of years. The creek cuts the schists and limestones of the Mount Distin mass and its upper portion is a series of waterfalls. The gravel lying along the lower part forms a deposit from 18 inches to 4 feet deep and from 60 to 70 feet wide. It is coarse, though it includes no bowlders not easily handled, and contains little fine sediment. The gold is smooth, bright, and coarse. No large nuggets have been found, the largest being worth only about $2. A little magnetite occurs with the gold.

Grub Gulch.—Grub Gulch heads in a low saddle between Nome and Snake rivers and flows in a channel bounded by rock walls of greatly sheared schist. The gravel is schist and quartz, but many granite bowlders are also found. A pay streak said to average about 40 feet in width and between 5 and 6 feet in depth, carrying $3.75 to the cubic yard, has been worked out. The gold was coarse and rough, but no pieces of greater value than $1.75 were found.

Grouse Creek.—Grouse Creek is 4½ miles long. The lower half of the stream occupies a north-south canyon-like valley, but the upper half of its valley does not have this feature so well marked. A large part of the water comes from springs at the base of Mount Distin.

The bedrock on the lower part of Grouse Creek is chiefly schist, but above Cold Creek the limestone beds of Mount Distin outcrop in many places. The surface deposits consist of limestone and schist with quartz, smaller amounts of greenstone, and scattered granite bowlders.

Mining has been carried on near Cold Creek and for some distance below. The gravel averages approximately 5 feet in thickness. About a mile above the mouth of Grouse Creek a pay streak 40 feet wide and from 1 to 3 feet thick, containing a large amount of limestone, was worked. The gold is bright and rough and rests on limestone bedrock. Near Cold Creek smooth-worn gold is found. It has worked down into cracks in the limestone, so that considerable labor is required to get it out.

There has been some prospecting also in the bench gravels between Grouse and Cold creeks, but the results were not especially encouraging. The gravel is well washed, and the deposits are from 4 to 24 feet thick.

Center Creek.—Center Creek and its tributaries, Flat, Wonder, and Saturday creeks, lie within the coastal plain. Their placers are of the type of reconcentrated stream placers, but their gold production is small. A claim on Saturday Creek where mining was carried on in 1900 showed 3 feet of gold-bearing gravel resting on a false bedrock and covered by 3 feet of "muck." Some of the gold was worn and bright, some rough. Most of it was rather coarse. Nuggets worth from 25 cents to several dollars were common, and one nugget

worth $14.50 was found. Magnetite, garnet, and a small amount of scheelite were the heavy concentrates accompanying the gold.

Cooper Gulch.—Cooper Gulch is a deep gash in the limestone mass of Anvil Mountain, but it also trenches some schist beds. Whether its waters flow into Flat Creek or Little Creek is difficult to say, for the stream spreads out upon the low fan-shaped deposit at the base of a rock bench through which it cuts and is lost on the tundra. A small area near this bench yielded good returns in gold, but in general mining has been conducted with little profit, and for several years nothing has been done on the stream.

Bourbon Creek.—Bourbon Creek empties into Snake River at Nome. It is 3½ miles long and has one principal tributary or branch, Holyoke Creek. Its gold deposits are a concentration from the tundra gravels and are not derived directly from a bedrock source.

Bourbon Creek flows in a broad trench cut in the coastal-plain gravels. This trench in its southern part has a width of several hundred feet and a depth of 12 to 15 feet. Toward the north it disappears, and the two branches flow through broad, shallow depressions in the coastal plain.

A section of gravel 1 mile from the head of the creek shows the following beds:

Section on Bourbon Creek 1 mile below head.

	Feet.
Moss and muck	2
Rock and blue clay	6
Gravel	1
Blue clay	½
Schist gravel with gold	1
Clay "bedrock."	

A second section half a mile farther north showed:

Section on Bourbon Creek one-half mile below head.

	Feet.
Blue and red clay	4
Gravel with gold	2
Sand.	

At the head of Bourbon Creek a small area of gravel mined in winter and piled in a dump yielded $12 a cubic yard when washed in the spring. Another claim a short distance lower on the creek had a gold-bearing gravel deposit 10 to 12 feet wide and 5 feet deep, which yielded $4 a cubic yard. The figures given represent a gold content probably somewhat larger than the average, and although considerable gravel sufficiently rich to yield a profit when worked by the usual and more primitive methods has been mined, a much larger portion must be handled more cheaply.

Nearly all the claims on Bourbon and Holyoke creeks are now under the control of one company, which has installed machinery for

dredging the gravel adjacent to the stream as well as the stream gravels themselves. The difficulty to be overcome is found chiefly in the frozen condition of the gravel away from the stream channel. The gravel near the creek is thawed in summer, but where "muck" and tundra vegetation are present it is frozen. Drill holes have been put down to bedrock on all the claims and show that gold is present in the lower marine gravels as well as in the upper creek deposits.

DRY CREEK AND NEWTON GULCH.

Dry Creek heads in the mountains north of Nome between Dexter Creek and the coastal plain and owes its name to the fact that during a month or so of a dry summer its upper half contains little or no running water. It has an average grade of 95 feet to the mile for the 6 miles of its length. About three-fourths of the creek lies within the coastal plain, so its placer deposits are partly a primary and partly a secondary concentration. The most productive portion is in the vicinity of the boundary between the plateau and coastal plain, but the concentrated deposits on the lower part of the stream are of importance also.

About a mile north of the present beach auriferous gravels from 3 to 5 feet thick were found resting on a slightly undulating clay bed. This pay streak is said to be 150 feet wide, and where mined to have an average value of about $5 a cubic yard. The gold is chunky, but pieces of the value of a dollar are rare. The pay gravel rests on the clay and is not found in or below it. Hematite, scheelite, and pyrite accompany the gold. Magnetite is present in the concentrates on the upper part of the creek.

North of the coastal plain Dry Creek flows through a V-shaped valley between Anvil and Newton Peaks. Little bedrock is seen along the channel, but the creek crosses the edges of schist and limestone beds exposed in the mountains on either side. Gravel extends from the coastal plain to the bench deposits at the saddle. The present creek bed, however, has produced little gold, although considerable work has been done on it near the mouth of Bear Creek.

An old channel of Dry Creek about 600 feet east of the present stream and 50 feet above it has been an important gold producer. This channel has been traced for three-quarters of a mile and has almost the same grade as the present Dry Creek. Its pay streak is from 20 to 60 feet wide. Partly rounded schist fragments, together with quartz and a few pebbles of greenstone and granite, constitute the bulk of the auriferous deposit, which is covered by 50 feet of gravel, angular schist fragments from the neighboring hills, and "muck." Part of the pay gravel is cemented with iron oxide. The north and south continuations of the channel have not been discov-

ered. At the north end a pay streak 4 feet thick and 60 feet wide rested on the schist bedrock and was covered by 20 to 60 feet of loose material. This claim is said to have yielded from $9 to $12 a cubic yard.

A short distance south of this locality the pay streak was 20 feet wide and was found in a well-defined rock channel. The shaft furnished the following section:

Section in shaft on old channel of Dry Creek.

	Feet.
Muck and silt	45
Fine sand	5
Pay gravel	½–2
Schist bedrock.	

It is reported that 6,000 eight-pan buckets from this place yielded $16,000. The gold of the old channel is coarse and not much worn. Many of the larger pieces contain fragments of quartz. Besides gold, the concentrates contain magnetite, ilmenite, scheelite, and garnet.

Newton Gulch joins Dry Creek about 3 miles from the coast. The stream rises on the south slope of Newton Peak, and is thus partly within the plateau region. Its branch known as the Left Fork has cut a deep V-shaped valley in the massive limestone forming the south slope of the mountain, but the only rock exposed in the gulch itself, except at the very head, is schist.

The auriferous creek gravels do not lie on schist bedrock, but for the most part rest on a bed of clay. The following section was measured near the mouth of the Left Fork:

Section near mouth of Left Fork of Newton Gulch.

	Ft.	in.
Sandy clay	3	6
Schist gravel with cross bedding		6
Sand	2	6
Gravel		7
Sand and gravel		8
Pay streak of schist gravel	3	
Clay bedrock.		

Another section still farther up the creek showed:

Section on Left Fork on Newton Gulch.

	Feet.
Moss and muck	3
Sandy clay	3
Gravel consisting of schist and limestone—the pay streak	3
Clay bedrock.	

In each of these localities the gold-bearing gravel lay on clay that was in turn underlain by other gravel of unknown depth. A prospect hole near the second locality mentioned was sunk 92 feet without reaching bedrock.

Along Newton Gulch the creek gravel disturbed in mining has a width of 30 to 150 feet and a thickness ranging from 2 to 27 feet. Near the mouth of Newton Gulch the deposit of pay gravel had a width of over 100 feet and was from 2 to 6 feet thick. Bedrock is 27 feet below the surface. The deepest pay gravel was located about a mile farther north, and rested on a clay seam 10 feet below the surface. It is thus seen that there is considerable variation in the occurrence of the gold-bearing gravel as well as of the other stream deposits accompanying it.

Auriferous gravels were discovered on the west side of the gulch three-fourths of a mile north of the forks, and mining has been carried on there for a number of years. The pay gravel lies above the stream, and the section exposed in mining is:

Section in Newton Gulch north of forks.

	Feet.
Tundra vegetation and peat	2
Sandy subangular gravel	6-8
Blue clay, false bedrock.	

This deposit does not appear to be directly connected with the stream placers. There is no defined channel, and the limits of the auriferous gravel are indefinite also. The gold is bright, and most of it is smooth. It is said that the average gold tenor of the gravel is $2 a cubic yard.

At the mouth of Newton Gulch the gold is coarse and bright, and as a rule the pieces are not much worn. In this locality the gold content was probably not less than $15 a yard, but the valuable deposits are very unevenly distributed along the stream.

NOME RIVER BASIN.

Nome River.—Nome River rises in the Kigluaik Mountains and follows a winding course southward to Bering Sea. The point where Buffalo and Deep Canyon creeks join, which is regarded as its head, is 26 miles north of Nome. Its valley is wide and is floored with a deep filling of gravels into which the river channel is incised to a depth ranging from 5 to 50 feet. In several places between Osborn and Darling creeks the river flats reach a width of a mile without attaining an elevation more than 50 feet higher than the top of the river banks. North of Darling Creek the valley narrows decidedly and below Osborn Creek it enters the coastal plain.

The elevation of Nome River at Dexter Creek is less than 50 feet, which allows the river below that point an average grade of 4 feet to the mile. From Dexter Creek to Hobson Creek the river level rises 107 feet, or at the rate of 8 feet to the mile, and from Hobson Creek to the mouth of Deep Canyon Creek it rises 393 feet, or at the rate of 44 feet to the mile.

No gold placers of consequence have yet been discovered on Nome River itself, although its tributary, Dexter Creek, has been one of the most important gold-producing streams of the region. Fine gold is found in the bars of the river, and a first-class modern dredge was built about 2 miles below the mouth of Banner Creek to exploit the river gravels, but the venture was undertaken without properly prospecting the ground and proved a failure. This is one of the few attempts yet made to work the gravels of Nome River in a truly commercial way.

In addition to Dexter Creek, a number of other tributaries have either produced important amounts of gold or hold possibilities for the future. In the first rank among these may be named Buster, Osborn, and Dorothy creeks. Colors of gold, however, may be found on almost any stream in the region.

Dexter Creek.—Dexter Creek, which joins Nome River 7 miles from the coast, is the one very rich creek near Nome that was not staked by the discoverers of gold on Anvil Creek in 1898. Mining began in 1899, and during most of the time since then the creek has been a large producer, although at one time its supply of gold was thought to be exhausted. At present, however, only one or two claims are being worked.

The creek is formed by the union of two small branches, Left Fork and Grass Gulch. These streams, together with Deer Gulch, a tributary of Grass Gulch, none of which is more than half a mile long, head in the three saddles between Dexter Creek on the one side and Nekula Gulch, Specimen Gulch, and Dry Creek on the other. From the forks to Nome River the length of Dexter Creek is 2¼ miles and its grade is 128 feet to the mile. The grade of the tributaries, however, is much greater. One other small branch, Grouse Gulch, should be named here, as gold has been mined in it.

Dexter Creek has cut a channel averaging 20 or 25 feet deep in the floor of the valley between King Mountain and Newton Peak. The walls for nearly a mile within the Nome River valley are made up of gravel, but above that portion they consist of schist and limestone of the Nome group. Limestone forms a large part of the bedrock. Its surface is deeply fissured, and underground streams flow through it. Gold-bearing gravel was extracted from some of the cavities to a depth of 30 feet.

The gravel consists essentially of schist, limestone, and quartz, but with these rocks are associated rounded granitic pebbles from 1 or 2 inches to 10 inches in diameter.

Most of the auriferous deposits that have been exploited were situated in the stream channel, yet two or three valuable placers were found on the benches above the creek. On the benches gold-bearing gravels still remain that will probably yield a profit when

mining conditions, such as water supply and freight rates, are more favorable.

Gold was found near the mouth of Dexter Creek at a depth of 5 feet below the surface, resting on a false bedrock of blue clay, which continues up the stream half a mile. The pay streak had a thickness of 3 feet and consisted of schist, quartz, limestone, and a small amount of greenstone. The gold was comparatively fine. Half a mile above this point the gravel reached a thickness of 6 feet, but the gold was found in the lower part. Large bowlders of limestone occur in the deposits, and a sticky yellow clay is abundant. A nugget worth $22 was discovered here.

About 1 mile from the mouth of this creek the pay gravel had a thickness of 7 feet and a width of 30 feet. It consisted chiefly of limestone fragments.

A short distance above Grouse Creek the loose deposits on the north side of Dexter Creek have a thickness of 20 feet. At the surface is 5 feet of yellow clay, which overlies 15 feet of angular and rounded fragments of schist, limestone, quartz, and granite. Mining here extended north into the gravel deposit, which may perhaps indicate the west end of the channel mentioned on page 103.

Near the forks of Dexter Creek the gravel accumulations widen. Their depth, too, is greater than on the central part of the creek. One pit 60 feet wide and 250 feet long showed from 6 to 10 feet of gravel resting on limestone and schist bedrock. The schist is slightly decomposed, allowing the gold to penetrate it for several inches; hence its upper part must be removed in mining. The limestone is much fissured and its surface is rough.

Gravel accumulations in the fissures were of great richness in places but required much labor to remove them. The gold was smooth and worn. Underground passages through the limestone are sufficiently large to carry away the natural flow of the streams as well as ditch water brought from other sources.

Bench gravels carrying gold were mined on the south side of Dexter Creek a mile from the creek's mouth, also on the north side a short distance farther west. On the south side of the creek a small area of gold-bearing gravel rested on limestone bedrock about 10 feet above the creek bed. The gold was taken in large part from crevices in the limestone.

On the north side of the creek the auriferous deposits were collected in a rock-cut channel 200 feet from the creek and 75 feet above it. Gold was found on the bedrock. The channel is nearly parallel with the present stream and was doubtless occupied by it at one time.

Grass Gulch.—Grass Gulch from a point near its mouth westward for a distance of about one-fourth of a mile has proved to be the

most valuable of the Dexter Creek placers. Its gold deposits are partly of the elevated-bench type and partly of the reconcentrated creek-deposit type. The stream is slightly more than one-third of a mile long and has a grade of about 450 feet to the mile. Deer Gulch joins it from the north 100 yards above its mouth. There is little or no running water in it during a part of the summer, and nearly all the water used for sluicing or hydraulicking is brought by the Miocene ditch.

A large amount of gravel has been taken from a pit that extends west from Left Fork for one-fourth of a mile, or nearly the full length of the gulch. The bedrock is a rough fissured limestone, from whose cavities and crevices the gold-bearing gravels frequently have to be removed by hand, as they can not be reached by the stream or by water from the giant.

Near the west end of the pit 25 feet or more of gravel, nearly all of which contains gold, is exposed. The section shows:

Section in pit on Grass Gulch.

	Ft.	In.
Moss and soil	2	
Brown gravel with well-rounded pebbles and clay	6	
Dark gravel streak		3
Brown gravel with well-rounded pebbles and clay	9	
Limestone bedrock.		

Schist, limestone, and quartz make up most of the gravel, but many granite pebbles and bowlders also are seen in it.

The greatest concentration of gold is found on bedrock. In general the gold is well worn and shows the effects of travel. Several nuggets of considerable size have been discovered, the largest of which was valued at $412.

Deer Gulch.—Deer Gulch heads near Dexter station and joins Grass Gulch a short distance above the mouth of that stream. The bedrock is schist and limestone. These same rocks make up the gravel deposits that occupy the gulch and join the bench gravels at Dexter. A small amount of gold was obtained from these gravels.

Left Fork.—Left Fork heads in the saddle between Dry and Dexter creeks. Its length is about half a mile and in that distance it falls 200 feet. The lower part of the stream flows in a channel cut in schist and limestone to a depth of 15 to 20 feet. A pay streak in this channel is 50 feet wide near the south end of the best ground, which extended up the creek for a quarter of a milc from Dexter Creek. One nugget worth more than $50 was found.

Grouse Gulch.—Grouse Gulch heads near the southeast end of the upper channel of the Dexter bench gravels. It is only one-fourth of a mile long and falls 200 feet in that distance. Its bedrock is schist and limestone, the limestone being limited to the lower end of the gulch.

Near the upper end of the gulch a section exposed on the east side showed:

Section in Grouse Gulch.

	Ft.	in.
Moss		6
Yellow clay	4	
Stratified sand and gravel	6	
Decomposed schist bedrock.		

In the lower part of the gravel bed a layer of quartz pebbles and many large angular pieces of schist contained some gold.

A short distance above this point a tunnel was driven from Grouse Gulch toward the Dexter Bench channel, and a small amount of gold was taken from it.

Buster and Lillian creeks.—Buster Creek flows into Nome River one-third of a mile below the mouth of Dexter Creek. It is 3½ miles long and has an average grade between its mouth and Good Luck Gulch of 100 feet to the mile.

Buster Creek forks 1½ miles above Nome River, the western branch being called Lillian Creek and the eastern branch retaining the name Buster. Above the forks Buster Creek occupies a narrow V-shaped valley cut through schist and limestone. Below the forks the valley broadens, and for the last half mile of its length the stream flows over the gravel floor of Nome River.

Buster Creek has been productive since mining began in 1899, and mining is still carried on, although nearly all the creek bed has been worked over. The gravel was shallow and the pay streak narrow. The richest portion of the creek lies between Davis Gulch and Good Luck Gulch. Schist, quartz, limestone, greenstone, and a small amount of granite made up the pay streak, which in some places rested on limestone and in others on chloritic and graphitic schists. The gold was coarse, and where the pay gravel rested on schist was found to have penetrated it to a depth of 18 inches. A nugget worth $18 was discovered.

Union Gulch, a steep, narrow gulch on the north of Buster Creek, is occupied by a small stream, which cut its channel in schist and limestone. The lower end of the gulch has a gravel deposit ranging from 10 to 20 feet in width and having a depth of less than 3 feet. The gravels here, which are like those of Buster Creek, yielded from $3 to $4 a cubic yard. The gold is coarse and iron stained. One nugget worth $16 was found.

A deposit of auriferous gravel was discovered near the mouth of Union Gulch, on the hill south of Buster Creek, 100 feet higher than the stream and at an elevation of 300 feet above sea level. Two pay streaks are present, on above the other. The upper one is 10 feet thick, but carries only a small amount of gold. The lower one

is much richer. It is 3 feet thick and lies in a well-defined rock-walled channel, which has been traced for about one-eighth of a mile. At the west end the northern channel rim disappears and the gravel spreads over the hillside. Eighteen feet of fragmental material, consisting of schist and quartz with bowlders of greenstone and granite rocks, is present in the channel, but below the channel the thickness of this deposit diminishes to 4 or 5 feet. A section of gravel a short distance east is as follows:

Section in Union Gulch.

	Feet.
Muck and slide rock	18
Low-grade auriferous gravel	10
Muck (probably frozen-slide deposit)	10
High-grade auriferous gravel	3
Iron-stained decomposed schist bedrock.	

A gold deposit of similar character was found on Grace Gulch, east of this place, at the same elevation and is possibly its continuation. The gold of the bench is like that of Buster Creek; it is coarse, but large nuggets are rare, and most of it is smooth and worn. Average pans from the lower pay streak are said to have contained from 10 to 18 cents in gold.

Lillian Creek occupies a shallow channel in a broad valley with gently sloping sides. Schist with occasional interstratified limestones form the bedrock. The gravel deposits are from 3 to 10 feet thick, and are in places covered by several feet of "muck." The gold is unevenly distributed, and the total production is small.

Osborn Creek.—Osborn Creek joins Nome River 5 miles from the coast and is its longest tributary. That part of the stream called Osborn Creek is about 10 miles long, but if the upper end, which is known as New Eldorado Creek, were included the length would be 14 miles. Osborn Creek flows in a broad upland valley, once deeply floored with gravel that has since been partly removed. Gravel benches are present along much of the stream, especially on the right side, and are prominent above St. Michaels Creek. The channel now occupied by Osborn Creek is intrenched in the valley floor to various depths in different parts of its course. At one point the valley walls have a height of 75 feet, but this is exceptional. The stream is confined by gravel banks in much of its upper course, but along its lower part the channel walls are schist with a few included limestone beds and have a height ranging from 10 to 20 feet. The width of the flood plain ranges from 100 to 200 feet, increasing at one locality, about 2 miles above St. Michaels Creek, to nearly 1,000 feet.

Schist, quartz, and greenstone are the most common rocks in the gravel deposits. Limestone also is present but in smaller amount than the three rocks first named. Granite bowlders are numerous on the benches and in the stream for several miles above Nome River. The great quantity of greenstone pebbles and bowlders is accounted for by the presence of the greenstone area west of Osborn Creek. Large greenstone bowlders are especially numerous along the lower 4 or 5 miles of the creek.

Little mining has been done on Osborn Creek, and that was confined to the middle portion. The gold-bearing gravels were there found to have an average width of 100 feet and to consist of 5 to 6 feet of rather coarse material resting on a clay bedrock. The gold is coarse and bright, and most of it is smooth and well rounded. Nuggets worth $1 to $20 were common. It is reported that a yield of $2.50 to $4 a cubic yard was obtained.

Gold is found on St. Michaels Creek about three-quarters of a mile above its mouth, and a small amount is taken out each year.

Washington Gulch.—Washington Gulch is about 1¼ miles long and joins Nome River 3 miles north of the coast. It drains part of the south side of Army Peak, but most of the stream lies in the lowland bordering the river. Gold is recovered from a deposit of fine sand resembling beach sand, which rests on bedrock and averages about 10 inches in thickness.

Dorothy Creek.—Dorothy Creek is a western tributary of Nome River and joins it 24 miles from the coast. The stream is less than 3 miles long; it flows in a steep, narrow V-shaped valley, which broadens slightly near its head and has a grade of about 290 feet to the mile.

The bedrock of Dorothy Creek includes schist, limestone, and a little greenstone. Mineralized quartz veins are numerous. These rocks, together with a small proportion of granite pebbles and bowlders from the Kigluaik Mountains, make up the gravel deposits. At a point little more than a quarter of a mile from Nome River Dorothy Creek leaves the narrow canyon-like part of its valley, and its gravel load is spread out in a broad fan-shaped deposit from 3 to 4 feet thick, in which most of the auriferous gravel is found.

Mining has been restricted to the lower mile of the creek and has proved very expensive, so that the profit, it is said, has been small. The gold is of lower grade than much of the gold from the Nome region and assays less than $15 an ounce.

Extra Dry Creek.—Extra Dry Creek rises on the north side of Newton Peak and joins Nome River 1¼ miles from Dexter Creek. It is 2 miles long and has a very steep gradient. The productive part of the creek occupies a narrow gulch cut in chloritic and feldspathic

schists that include a few limestone beds. A section of the gravel here showed:

Section on Extra Dry Creek.

	Feet.
Muck	1
Sandy clay	1
Gravel consisting of schist and quartz	6
Schist bedrock.	

The gold was coarse in this portion of the creek, but became finer downstream. One nugget had a value of $13. The creek appears to be exhausted at present, as little work has been done for several years. It is probable that the total production is less than $20,000.

Banner Creek.—Banner Creek joins Nome River 3¼ miles north of the mouth of Dexter Creek. It is less than 3 miles long and carries only a small quantity of water. The lower half mile of the creek is within the valley floor of Nome River. Above that part the creek has cut a deep channel in the schist of its valley. The rock exposed is chiefly schist, but much limestone is also present. The schist and limestone have been faulted and are cut by quartz veins.

Mining operations on a small scale, yielding a correspondingly small production of gold, have been carried on below Slate Creek.

Basin Creek.—Basin Creek is 3 miles long and joins Nome River 14 miles from the coast. The lowest half mile of the creek lies in the Nome River valley floor, but above that part the stream flows for a mile through a narrow valley, which broadens out toward the east near the point where the creek forks. There has been some mining on Basin Creek between the forks and Nome River valley.

The bedrock is schist and limestone. Several limestone beds outcrop along the lower part of the creek, and a much heavier bed extends across the valley near the forks. Heavy limestone beds are also seen in the mountains on either side.

Schist, limestone, and a small amount of greenstone constitute the gravel deposits, in which an unusually large proportion of bowlders is present. A section of the gravel exposed in mining is as follows:

Section on Basin Creek.

	Feet.
Soil	2
Rounded creek gravel	3
Coarse angular material with clay (the pay streak)	12
Bedrock.	

At this locality the pay streak had a width of nearly 150 feet. The gold was coarse, bright, and rough, and was associated with ilmenite, hematite, and scheelite. Nuggets worth $2 were found, some of which still showed their crystalline form. It is estimated that the richest

gravel carried not more than $6 a cubic yard, and that the total production did not exceed $30,000.

The drainage basin is small, yet water was obtained to operate a small hydraulic plant. A much larger supply, however, would be necessary if mining were done on an extensive scale. A gradient of about 150 feet to the mile along the lower half of the creek gives considerable advantage in the disposal of tailings over many of the other streams described.

Divide Creek.—Divide Creek is a small stream slightly over 1 mile long, heading in the saddle between Stewart and Nome rivers. During the construction of a ditch to carry water to Dorothy Creek gravel deposits were discovered in this saddle and along the hill slope on the Nome River side. Quartz with free gold was found, and one nugget of quartz and gold weighing nearly three-fourths of a pound was uncovered. This gold is thought to have come from the slopes of Boer Mountain on the north and might perhaps be classed with the residual deposits. No attempt has been made to exploit the gravel in a systematic way.

Boer Creek.—Boer Creek has been partly described in connection with the residual placers (p. 76), so that now only its creek gravels need be considered. It was seen that the creek flows in a steep, narrow valley cut in graphitic schists and limestones. The stream gradient is about 500 feet to the mile; but there is not sufficient water for mining purposes, as the entire gathering ground of the drainage basin is not more than 1½ square miles.

Although part of the placer gold taken from Boer Creek is residual, another part owes its concentration to stream action. Gold-bearing gravels are confined to the narrow creek channel and range in thickness from 18 inches to 8 feet. These deposits consist of schist and limestone, with a large amount of granite from the mountains on the north. In the channel near the head of the stream is a recent conglomerate made up of schist and quartz fragments cemented by iron oxide. A similar deposit was noticed on a number of small streams in the Stewart and Sinuk river basins. Two grades of gold were obtained from this creek; one assays $18 an ounce, but the other is lighter colored and assays only $16 an ounce.

STREAMS NOT INCLUDED IN NOME AND SNAKE RIVER DRAINAGE.

Placer gold has been mined on several streams not belonging to the Nome and Snake River drainage systems. These streams, however, have yielded only small amounts of gold.

Hastings Creek.—Hastings Creek is about 3 miles long and flows into Bering Sea 3 miles west of Cape Nome. Its important placers belong to the "second beach," described on page 41. A small quantity of gold, however, has been taken out near the head of the creek

and some from its lower part south of the old beach line. Hastings Creek lies within the coastal-plain deposits, and its gold is a reconcentration from the tundra gravels. That taken from the lower course of the stream was doubtless derived largely from the old beach, which it has partly removed.

Fred Gulch.—Fred Gulch is a small tributary of Stewart River rising on the north side of Mount Distin. Its upper portion trenches the heavy limestones of the mountain, but the lower portion has carved its channel in schist and the gravel floor of Stewart River. A small amount of gold, probably little more than wages for the man working, has been taken from the stream gravels below the main limestone mass.

Hazel Creek.—Hazel Creek, 2 miles long, is a tributary of upper Flambeau River. Its upper valley is narrow and steep, but for the last half mile of its course it crosses the valley floor of Flambeau River. Gold-bearing gravels are found near the place where the creek leaves the hills, and a hydraulic plant supplied by a ditch with water from the head of Flambeau River was installed to exploit them but was not completed when the Survey party visited the vicinity.

HIGH-BENCH PLACERS.

Character and distribution.—High-bench placers are stream deposits that differ from the stream placers already described chiefly in their position relative to the neighboring stream courses. They are remnants of deposits laid down by a former drainage system and now in large part removed by later stream erosion, including that of the present-day streams.

Elevated gravel deposits are known to be present in several localities within the Nome and Grand Central quadrangles. Only a few of them, however, have been producers of gold. The elevated gravel deposits in the three saddles at the head of Dexter Creek have been described. (See p. 39.) They appear in the divides between Deer and Nekula gulches, between Grass and Specimen gulches, and between the Left Fork of Dexter Creek and Dry Creek. All these localities have considerable economic importance, although the deposits at the head of Dry Creek now appear to be practically exhausted. It is worthy of note that the presence and the probable importance of the high-bench placers at the head of Dexter Creek, like that of the buried beaches of the Nome coastal plain, were predicted by Schrader and Brooks[1] before these placers were discovered.

Dexter station.—Dexter station, in the divide at the head of Deer Gulch, has an elevation of 594 feet and is practically in the lowest part of the saddle between King Mountain and Dexter Hill. The

[1] Schrader, F. C., and Brooks, A. H., A preliminary report on the Cape Nome gold region, Alaska: Special publication U. S. Geol. Survey, 1900, pp. 12, 16, 20.

watershed is only 100 or 200 feet north of it. Placer gold was discovered in the gravels near this point in 1900, and mining has been carried on ever since, some of the ground proving to be very rich.

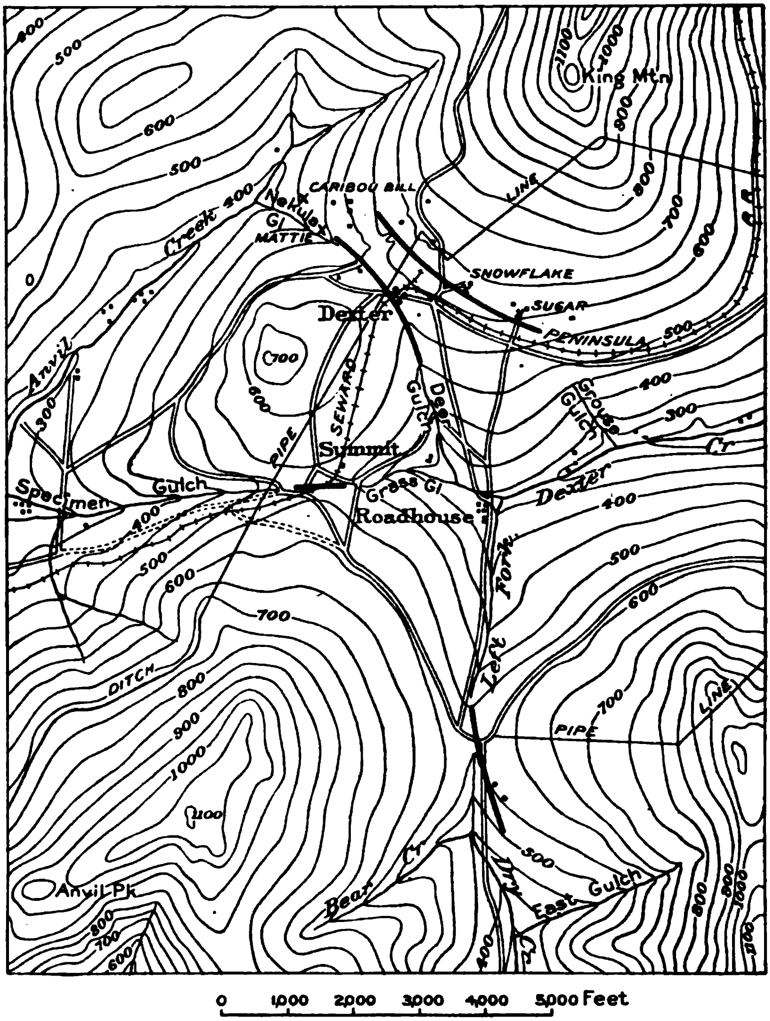


FIGURE 11.—Sketch map showing (by heavy lines) the position of pay streaks or old channels in the high-bench gravels at the head of Dexter Creek.

At Dexter station divide the thickness of the gravel is about 135 feet. The bedrock divide, however, does not correspond with the surface divide, but lies several hundred feet north of it, as a consequence of which the gravel deposit thins out in that direction. Gravel extends northeastward on the slope of King Mountain to an elevation of 650 feet above sea level, or about 50 feet above the

saddle. It also extends southeastward toward Grouse Gulch, near which it finds topographic expression in a broad, low bench, and southward toward the head of Grass Gulch, but it is not seen on the slope west of the saddle.

The bedrock is schist, which includes several beds of limestone. These rocks are much disturbed, faulting has taken place, and the structure is uncertain. Schist, quartz, and limestone form the gravel deposits. A few rounded granite bowlders are found, but it is probable that they occur chiefly near the surface. The fragments are angular. Flat pieces of schist a foot or more in greatest diameter are numerous, and the deposits have the characteristics usually found in stream wash or in rock waste that has not traveled far.

The rich gold-bearing gravel at Dexter station comprises two distinct pay streaks in old stream channels (fig. 11).

The lower streak lay upon bedrock and extended from the head of Nekula Gulch to Deer Gulch, sloping toward the south. It was practically at the surface on Nekula Gulch, but is 135 feet below the surface at Dexter station. The workings have exposed it continuously from Nekula Gulch to Deer Gulch. Unfortunately, mining began at the north or higher end of the old channel, and although the work was carried on from a number of shafts all the gravel had to be hauled up the slope before hoisting. The slope in places is so steep that two men were required to push the cars.

The lower pay streak comes to the surface on the Mattie claim, north of the station and just east of the head of Nekula Gulch, and was worked in an open cut about 30 feet deep. This is the place where the high-bench placers were first found and is the north end of the pay gravels passing under the divide at Dexter station.

The upper pay streak lies north and east of Dexter station. At a point 500 or 600 feet northeast of the station pay gravel was reached at a depth of 100 feet, or 75 feet above the level of the nearest part of the lower pay streak. From this place the upper pay streak extends northwestward toward Anvil Creek and southeastward across the south slope of King Mountain toward Grouse Gulch, in which direction the thickness of overlying gravel deposits increases.

The principal claims located on the upper pay streak are, from north to south, the Mattie, which includes the north end of both pay streaks; the Lena and Gambrinus, whose common boundary line cuts the upper pay streak lengthwise; the Snowflake; and the Sugar. Collier visited these workings in 1903, and his notes have been used freely in the following descriptions of the bench gravels and the placers.

On the lower or west end of the Mattie claim 30 feet of gravel was exposed in a pit measuring 50 by 150 feet. The bedrock con-

sists of much-faulted chloritic and graphitic schist with some limestone. Small quartz veins cut the schist and have been found from assays to carry traces of gold. Bedrock outcrops on the claim near the head of Nekula Gulch. The loose deposits exposed in the cut comprised 5 or 6 feet of light sandy wash underlain by 25 feet of gravel, which rested on schist bedrock. This gravel in places was well stratified and of brownish color but toward the east contained considerable clay and was less well bedded. A few granite bowlders were found at the surface. Gold was found on bedrock and in the upper 2 feet of the decomposed schist. It was bright and waterworn, averaging about 10 or 12 colors to the cent.

On the east end of the claim a shaft was sunk 65 feet through gravels to schist bedrock, which at this place is 50 feet higher than at the open cut.

Pay gravel was found in a channel ranging in width from 15 to 150 feet and was traced into the pay streak of the Lena and Snowflake claims, thus proving it to be a part of the upper pay streak. The following section was exposed by the shaft:

Section in shaft on Mattie claim, near Dexter.

	Feet.
Turf	1
Sand and gravel	60
Pay gravel	6-9

About one-fourth of a mile southeast of the Mattie claim and directly east of Dexter station is the principal opening of the Snowflake mine. A shaft 130 feet deep was sunk to bedrock, exposing the following gravel section:

Section in Snowflake shaft, near Dexter.

	Feet.
Muck and gravel with bowlders and pebbles of gneiss and granite	5
Silt and gravel	125
Quartz chlorite schist, bedrock.	

The gravel is nearly all of local origin and is made up of schist and quartz fragments showing little wear. Only a few granite pebbles were found, and they were at the surface. Most of the rock fragments forming the gravel have subangular edges and evidently have not traveled far. They are the wash of a small stream. From 3 to 9 feet of the gravel directly above the schist was gold bearing.

The pay streak at the foot of the shaft occupied a rock channel running S. 60° E. and averaging about 100 feet in width. This channel is shallow, the southern rim rising only a foot or two above the gold-bearing gravels.

Seventy feet east of the foot of the shaft, on the 130-foot level, the bedrock pitches below barren gravel, which underlies the pay streak at this place. A shaft was sunk here and reached schist bedrock at a depth of 100 feet, thus giving a total thickness of 230 feet of gravel. The lower end of this shaft followed a slickensided schist wall on the south for 15 or 20 feet. There is evidently a fault here extending from northwest to southeast, which is older than the gravel deposit, for it has not disturbed the gravel. Another pay streak lies on bedrock in this second shaft.

The surface deposit at the Snowflake claim is frozen to a depth of 90 feet. Below that the gravel is dry, practically no water entering the workings except from the shaft. Gold was found in all the gravel, but is not present in sufficient amount to be recovered with profit from any of it except the pay streak under the conditions prevailing at the time the mining was carried on. Only gravel averaging from $6 to $7 a cubic yard was hoisted, and doubtless much ground remains that would yield good returns if a suitable water supply were available, so that the gravels could be handled by hydraulicking.

The gold was bright and coarse. Its rough edges showed that it had not been carried far by the stream. The larger nuggets were porous, and many of them included pieces of quartz and calcite. One nugget weighing 9 ounces 9 pennyweights was found.

About 600 feet southeast of the Snowflake is the Sugar claim. Gold-bearing gravel of low grade was here reached at a depth of 100 feet; this rested on an older gravel deposit like that at the Snowflake. Drill holes showed that bedrock lies 205 feet below the surface. The lower deposits contain a small quantity of gold, but only those at the 100-foot level were exploited. This pay streak is here 70 feet lower than at the Mattie claim, 3,000 feet northwest, which gives it an average slope of 1 foot in 40 feet.

About 300 feet southeast of the Sugar claim a shaft was sunk, from which the following section was obtained:

Section in shaft southeast of Sugar claim, near Dexter.

Muck and silt	feet	4
Loose gravels with colors	do	25
Decomposed chloritic schist	do	51
Washed gravel and silt	inches	10
Schist	feet	20

The 10 inches of washed gravel was thought to be continuous with the pay streak of the Sugar claim, but it carried no gold.

Exploratory tunnels driven along bedrock to the north and to the south showed that the gravel pinched out in these directions. Tunnels were driven west and north also in the schist from the bottom

of the shaft, and an upraise to the 75-foot level was made in the western tunnel without discovering important gold-bearing deposits, although a thin bed of gravel containing a little gold was revealed.

To summarize the foregoing descriptions, it may be said that the elevated bench gravels near Dexter station, except a small proportion of those found at the surface, are of local origin. These gravels occupy the saddle between King Mountain and the hill on the southwest and mantle the mountain's lower southern slope. In the saddle they are 135 feet thick, but about 1,000 feet east their thickness increases to a maximum of 230 feet. North of the divide the gravels thin out.

Two principal pay streaks have been developed and largely worked out. The lower one extends from the head of Nekula Gulch to Deer Gulch and has a southerly slope. The upper pay streak begins a short distance east of Nekula Gulch and extends southeastward to the head of Grouse Gulch, a distance of about 3,000 feet. These two pay streaks have a difference in elevation of 50 feet at their north ends, and east of Dexter station this difference increases to nearly 75 feet. The lower pay streak lies on bedrock, but the eastern one rests in some places on bedrock and in other places on older gravel. Gold is not confined to the main pay streak of the eastern claims, for in the Snowflake mine it is found also in another pay streak 100 feet lower—that is, 230 feet below the surface. It is not known whether there is any connection between the lower pay gravels of the Snowflake and those found in the saddle, but apparently there is none. In general the gold is angular and rough, yet at the north end of the lower pay streak smooth, waterworn gold was found.

Specimen and Grass Gulch divide.—The saddle between Specimen and Grass gulches is 3,000 feet south-southwest from Dexter station and is 50 feet lower, or about 540 feet above sea level. This saddle is crossed by the railroad tracks and by the wagon trail. It is occupied by gravels which fill a narrow rock cut running almost directly east and west. At the summit the gravel has a thickness of 106 feet. The total width of the deposit probably does not exceed 600 or 800 feet, and development work was carried on along an east-west line for about the same distance, although the gravel extends to the heads of Grass and Specimen gulches.

No section was obtained, but the dumps show fine sand and silt containing many bowlders of schist and granite. All the material is considerably waterworn. On the east side of the saddle, 150 feet from Grass Gulch and 500 feet from the railroad, the surface material shows 20 feet of yellow clay with some sand and rounded pebbles. Granite pebbles are abundant on the surface and appear all along the hill slope to the head of Dry Creek.

The gold-bearing gravel has a thickness of 6 to 7 feet. The fragments are waterworn and contain much granite, though the chief constituents are schist and limestone. The pay streak ranges from 50 to 80 feet in width and is overlain by clay in some places. The gold-bearing gravel lies on bedrock in a fairly well-defined channel running from east to west. All the deposits are frozen.

The gold obtained here was worn and smooth. Many nuggets were found and all showed the effects of travel. One nugget, valued at $138, was taken from this place. Some of the gravels were very rich, but the pay streak averaged probably about $7 or $8 a cubic yard.

Dexter and Dry Creek divide.—Between Dry and Dexter creeks is a broad saddle whose elevation above the sea is 570 feet. It is thus 24 feet lower than the saddle at Dexter station and about 25 feet higher than that at the head of Grass Gulch. This saddle, like the other two, is occupied by gravel deposits whose surface is nearly flat, but slopes slightly toward the south. The gravel is gold bearing, but the rich portion is now worked out.

Development work extended along a nearly north-south line for 2,000 feet, following a broad, shallow channel in bedrock, in which the best gravel lay. Near the summit the channel lies in the middle of the saddle; to the south, however, it is situated a little east of the head of Dry Creek. Its highest point is perhaps 1,000 feet farther south than the lowest part of the saddle. It slopes to the north and is 40 feet lower at the north than at the south end. The gravel deposits increase regularly in thickness from 35 feet in the most southern shafts to 70 or 75 feet in the northern ones. East and west from the channel line the thickness diminishes rapidly.

The gravel consists essentially of subangular fragments of schist. Much of it is feldspathic; it is all more or less decomposed and some is iron stained. There is a comparatively small amount of vein quartz, a large percentage of which is derived from quartz-chlorite-albite veins such as appear on the hill on the east and on Newton Peak. A little limestone also is present, and a very few granite pebbles and bowlders are seen. Whether the granite occurs in the deep gravels was not determined, but it is common on the hill slope to the northwest.

A shaft near the middle of the workings showed the following section:

Section in shaft on divide between Dexter and Dry creeks.

	Feet.
Muck and slide rock	16
Washed gravel with some gold	12
Soft sandy soil	2
Soil, peat, and slide rock	22
Stream gravel	10
Decomposed schist bedrock.	

None of the deposits are frozen. The bedrock in most places is schist, but toward the north schist gives place to limestone.

Gold-bearing gravel was found on bedrock in the broad shallow rock channel described. It has a thickness of 2 to 3½ feet and consists of light-brown sandy material containing pebbles of schist with some quartz and limestone. Gold was not confined to this channel, although the richest gravels were found there. Both on the east and west auriferous gravel was worked with profit. The gold was coarse and well rounded, yielding probably from $6 to $12 to the cubic yard of gravel. Some pans of $3 to $4 were obtained.

It is possible that the placers found in the old channel 400 or 500 feet east of the present bed of Dry Creek where it leaves the hills to cross the Nome tundra are a continuation of the gold-bearing gravel in the saddle at the head of the stream. No connection between them has been established, however, and if they were continuous, the intermediate portion has been cut through by the small easterly tributaries of Dry Creek. This old channel has been described in connection with the gold-bearing gravels of Dry Creek (p. 90).

A somewhat similar occurrence of high auriferous gravel appears on the south side of Buster Creek and has been described in connection with the Buster Creek placers (pp. 96–97). It lies at an elevation of 325 feet above the sea, or about 125 feet above the stream, hence it is somewhat lower than the high gravels already described. What relation, if any, there is between them is not known.

Summary.—The elevated gold-bearing gravels at the head of Dexter Creek are found in the three low saddles in the watershed between the Snake and Nome river drainage areas. These saddles have elevations ranging from 540 to 594 feet above the sea. The deepest as well as the most productive of the accumulations is that at Dexter station, where the greatest thickness of gravel measured was 230 feet. Next to the Dexter station gravels in point of thickness are those at the head of Grass Gulch.

The great mass of the material is made up of subangular fragments, apparently of local origin, consisting of schist and quartz with a small amount of limestone. Clays and sands are associated with them. Well-rounded granite and gneiss pebbles are found in the surface deposits at each of the localities and are abundant at the head of Grass Gulch and on the hill slope at the southeast. At the Grouse Gulch locality they are found also in some of the lower gravels.

Gold is present in all the gravels, but only a part of them were sufficiently rich to be mined with profit at the time when work was being carried on.

The most important gold-bearing gravel formed well-defined pay streaks sloping toward Dexter Creek. These pay streaks represent

the beds of former streams, which in some places cut distinct channels in the bedrock but in others flowed over older surface accumulations. Such streams could not exist under present conditions, and it is evident that they were part of a drainage system that differed in considerable measure from the one we now see. The streams that deposited the gravel and gold must have carried much more water than collects in the present drainage areas. Moreover, the worn granite bowlders and pebbles give conclusive evidence that the top gravels are derived in part from a distant source, although the lower beds consist of material like the rock of the surrounding hills.

In themselves these high gravels give no conclusive evidence of land elevation, unless it can be shown that the granite bowlders were laid down when this area was below the sea or were deposited by a stream near sea level.

As the three old channels converged in the Dexter Creek valley, it is probable that the gold found in Dexter Creek was largely a reconcentration from the older gravels.

BEACH PLACERS.

General features.—The Nome beach placers are of two kinds—those of the present beach and those buried in the coastal-plain gravel deposits. They do not differ in origin, however. The buried beaches were once like the present one; they were beaten by the waves of Bering Sea, like the beach of to-day, and they were washed by shore currents such as now sweep along the coast. Their chief peculiarities are that they have been covered with a mass of later deposits and, with the exception of the "submarine beaches," have been elevated above sea level. Some account of the old beaches has already been given in the description of coastal-plain deposits (pp. 41–44), but it will be necessary to restate some of the important facts and consider them more particularly with regard to their economic bearing.

Five or six ancient beaches, more or less well defined, may be recognized in different parts of the coastal plain and have received local names. Many others are reported, and it is evident from a study of the way in which the coastal-plain deposits were formed that there may be a very considerable number, but it by no means follows that they are all economically important. Two of the beaches are of especial interest in a consideration of the placers, because the richness of their gold-bearing gravels caused them to be traced for long distances and to be studied with great care. They are known as the "second" and "third" beaches from the order of their discovery, the present beach being regarded as the first. Both are nearly parallel to the present coast line but converge toward it in the direction of Cape Nome, where all three come together. The "intermediate

beach," the "submarine beaches," and the somewhat doubtful "Monroeville beach" are not so rich and are less well known. These beaches, essentially similar in most respects, form one of the most noteworthy features of the Nome placer district.

Present beach.—Sixteen miles of coast line is represented on the Nome map. The western half of this line is broken by the mouths of Nome and Snake rivers and includes the most productive part of the present beach. The eastern half is cut by a few minor streams, and only one or two small sections of it have been found to contain notable amounts of gold.

This coast line is slightly bowed toward the north, but is so nearly straight that one scarcely realizes the curvature as he looks along the shore. The beach varies in width from about 250 feet to 300 feet and has a southerly slope of about 1 foot in 10. This slope is greater in some places and is less in many places. On the north is a low escarpment of silt and tundra vegetation locally underlain by ice and having a height exceeding in a few places 8 or 10 feet, though in most places not greater than 3 or 4 feet.

The gravel on the beach surface is mostly rounded quartz associated with a considerable amount of schist and a little granite. The granite, like the quartz, is well rounded, but most of the schist fragments, although their edges are ground away, have one dimension very much smaller than the other two. A few bowlders are seen, but in general the pebbles do not exceed 2 or 3 inches in greatest dimension. Some of the bowlders were probably carried to the beach by floating ice.

Fine sands predominate near the water, but in the higher part of the beach, gravel is more conspicuous than sand. In places the surface material is almost entirely composed of red garnet, or "ruby sand," as it is called. It is especially common near Cape Nome, but is found in many other localities. The beds of ruby sand are commonly not more than a few inches thick and extend in a horizontal direction for short distances only. Where buried under other gravel they lie in lenticular beds exactly similar to those found in the buried beaches. This form is characteristic of all the beach deposits. The gravel beds are not continuous, like those laid down in deep water, but consist of overlapping lenses. Besides garnet, the minerals magnetite, ilmenite, scheelite, pyrite, and mica have been noted in the beach sand, but the great bulk of it is quartz.

A section of the beach placers shows from 1 to 6 or 7 feet of sand and gravel overlying a blue clay "bedrock." The clay bed or rather beds, for the clay is not known to extend continuously along the shore, slope toward the sea and are nearest the surface at the upper side of the beach—that is, their slope is greater than that of the beach.

Other thin clay beds or seams are distributed in the gravels above them.

Most of the beach gold was found to be concentrated in the sands overlying the blue clay, but in places more than one pay streak was uncovered. The principal pay streak ranged in thickness from 6 inches to 2 feet. In nearly all places where gold was found in quantity a large amount of ruby sand was present in the pay streak and usually some magnetite also, although magnetite constitutes but a small proportion of the concentrates.

The pay streak, like the other gravel deposits, was lenticular, its dimension parallel to the shore being greater than at right angles to it. Gold was much more highly concentrated in some localities than in others. The richest sands are said to have carried about $1 to the pan. That part of the beach adjacent to the mouth of Snake River yielded a major portion of the beach production, yet the whole coast line from Cape Nome to Penny River afforded valuable gold-bearing gravels. The gold averaged from 70 to 80 colors to the cent and was therefore regarded as fine gold. Coarser gold has been found in a few places, but nuggets worth a dollar were rare. On the sandspit between Snake River and the sea coarse gold with nuggets up to the value of $6 and $8, similar in character to gold found on the lower end of Bourbon Creek, was taken out. There still remains much gold in the present beach at Nome, and each summer a few men may be found washing the sands, but the most highly concentrated deposits have been removed, and the ground has been so thoroughly searched for rich spots that only by handling the gravels in a large way and with machinery for saving all the valuable content could mining be carried on with much profit. One curious feature of the beach gold is that much of it is now found to be amalgamated with mercury lost from the sluice boxes. There is so much mercury in the beach that one can hardly wash a pan of the lower gravel without finding the little white globules.

Second beach.—The second beach was the earliest of the ancient buried beaches to be discovered, but did not attract attention till two or three years after the gold deposits of the present Nome beach were found and was not itself thoroughly exploited till a year or more after its deposits became known. It extends eastward from a point about two-thirds of a mile north of Nome for 8½ miles to Hastings Creek, where its distance from the sea is about a quarter of a mile.

During the winter of 1904–5 many holes were sunk along the line of this beach between Nome and Hastings Creek and helped to determine more accurately than before the location and position of its pay gravel throughout the greater part of its extent. The pay gravel lies at the foot of a well-defined bench, which is continuous throughout

much of the portion of the beach mentioned, except where it has been cut through and removed by some of the larger streams. The pay streak, as is well shown by the line of tents and cabins erected on the claims along its course, forms a nearly continuous deposit almost as constant in direction as the present beach, to which it is approximately parallel.

The gold-bearing gravel, which rests on a clay or in places a gravel "bedrock," ranges in thickness from 3 or 4 inches to 2 or rarely 3 or more feet and lies, as a rule, from 20 to 35 feet below the surface. On several claims its depth below the surface is about 40 feet and in a number of places it is less than 10 feet. The width of the gold-bearing deposit ranges from 25 to 100 feet, but averages between 35 and 40 feet. At three widely separated localities its altitude above sea level is 37 feet. It has also been observed that the pay streak has a dip toward the south amounting at one point to 4 or 5 feet in the width of the pay streak at that place, which was 50 feet. In some places—for example, on Peluk Creek, Otter Creek, and Nome River—the gold-bearing gravel is less regular in its longitudinal extent and appears to have been cut through or scattered by the streams. Possibly there were indentations of the shore line at the mouths of these streams interrupting its regularity, although there are none along the present beach, the mouths of streams being characterized rather by delta deposits.

The gravel from which the gold is taken is a true beach deposit and, like the beach material of to-day, contains a large amount of "ruby sand" and some marine shells. Walrus tusks and driftwood have been taken from several shafts.

All the deposits from the surface down are permanently frozen. The gold is fine, like that of the present beach, yet in one place near Otter Creek nuggets were found, and according to T. M. Gibson were probably derived from a near-by schist ridge slightly above the beach level. The gold deposits of the second beach were much smaller in amount than those of the present beach.

Third beach.—The third beach was discovered late in the fall or early in the winter of 1904. During the following summer operations on it were confined to the immediate vicinity of Little Creek, and not till the winter of 1905–6 was its eastward extent determined and the ground opened for mining. This old coast line skirted the hills back of Nome and extended in a broad arc, bowed toward the north, from Cape Nome on the east to Cape Rodney on the west—a distance of 27 miles. At Little Creek, where it was discovered, the third beach is 3½ miles from the present beach, but eastward from that point the two gradually converge. The third beach lies above present sea level at an elevation variously given as 70 to 79 feet, depending probably on the part of the deposit chosen for making the

measurement. It is thus above the level of Nome and Snake rivers at the points where it intersects their courses. These two streams flow through valleys in the coastal-plain deposits that are younger than the third beach, and in forming these they removed parts of the third-beach deposits, making two important gaps in the beach within the area considered. A smaller gap, formed by Hastings Creek, should also be mentioned. The gap at Nome River is 2½ miles broad; that at Snake River extends west from Little Creek at least as far as Sunset Creek.

The best-known and richest part of the third beach is between Little Creek and the head of McDonald Creek. East of Nome River the gold content is much smaller, and so far as is known at present the beach deposits are less well defined. The gold-bearing gravel lies at the same elevation above the sea wherever the elevation has been determined, but its depth below the surface depends on the surface topography. Where valleys are cut below the deposit it appears at the surface, and it lies at a maximum depth of 120 feet near the head of Bourbon Creek.

The beach deposits are of marine origin, yet some of the rich gold-bearing gravel associated with them and a great deal of the overburden are not. This is evident from the character of the gravel. The difference between marine and stream deposits is noticed in both their vertical section and their horizontal distribution and is well shown in the stretch of beach between Little and McDonald creeks. Near Little Creek stream deposits are intermingled with well-washed marine gravel and form a large proportion of the whole. Toward the east the amount of stream gravel decreases and marine gravel becomes predominant.

Mining operations and drilling[1] have shown that the third-beach deposits between Little Creek and a point about halfway between Newton Gulch and Otter Creek rest for the most on a bedrock of schist having small included beds of limestone. The bedrock dips gently below the third beach from the vicinity of Otter Creek to McDonald Creek, where it is 20 feet lower, then falls more steeply to a point below sea level near Nome River, rises within 12 feet of the third beach near Irene Creek, and finally pitches below sea level, not to rise again to the third-beach level till the hills of Cape Nome are approached.

A description of the unconsolidated deposits overlying the third beach has been given (pp. 41–42). They consist of a varied association of marine and stream gravel and sand overlain by and in places interstratified with "muck" and vegetation. The third beach de-

[1] The writer is indebted to the paper by T. M. Gibson previously cited for some of the facts concerning the Nome beaches, particularly the third beach.

posits resemble those of the present beach in most respects, except in the important one that they contain a greater proportion of stream gravel in certain places. They have a thickness ranging from 5 to 12 feet and a width, including the so-called "slough over," of 300 to 600 feet. The "slough over" is a minor line of marine deposits lying immediately south of the main beach and containing a pay streak of considerably smaller value. It is separated from the third beach by a narrow zone occupied in part by a bed of quartz cobbles and small bowlders. Its origin is not known with certainty, but it has been explained as an off-shore bar.

The third beach, like the present beach, has a slope of about 1 foot in 10, but is slightly steeper in the seaward than in the shoreward half. It is made up of elongated, lenticular beds of gravel and sand laid down by the waves, but at three localities the ancient streams that emptied into the sea along this beach have contributed quantities of débris that obscured the character of the marine deposits. These localities are at Little Creek, the old mouth of Anvil Creek; near the head of Bourbon Creek, the old mouth of Dry Creek; and near Irene Creek, where, with little doubt, Osborn Creek once joined the sea.

The placer deposits in the vicinity of Little Creek have been described as follows:[1]

The gold deposits are deep. The average depth of the various shafts is between 30 and 35 feet, but this is exceeded in a few instances and reaches 50 feet. A heavy covering of muck and moss, with a thickness varying at different places from 12 to 23 feet, overlies the gravel, and all is frozen from the moss down. The gravels are not entirely similar at all localities, either in the thickness or in the character of the beds. Some deposits are apparently well-washed beach sand, others were without doubt laid down by streams. At a distance of 1,000 or 1,200 feet east of the railroad track beach wash with a thickness of 5, possibly 7 feet, rests directly on bedrock (mica schist), and is overlain by stream deposits. A short distance west of this the gravel lying on bedrock is probably of stream origin. Still farther west, near the railroad, thin beds of clean rounded gravel are interstratified with stream wash. Beds containing bowlders up to a ton in weight overlie the workable gravels in some places and are a constant source of danger in mining, especially during the summer months, when the roof is weakened by thawing. These bowlders are also present on the bedrock and are found not infrequently in the muck overlying the gravels.

Nearly all the deposits from the surface to bedrock carry a certain amount of gold, but the rich gravels are found well down, in some places resting directly on the schist and in others at a height of 5 or 6 feet above it. The gold-bearing gravels of present economic importance have a thickness of between 4 and 5 feet, but in one instance, where the material removed formed a lenticular mass, the thickness was 16 feet. Thin elongated lenses or beds of reddish sand, called "ruby sand," whose color is due in some cases to small grains of red garnet and in others to iron oxide, occur throughout the pay

[1] Moffit, F. H., Gold mining on Seward Peninsula: Bull. U. S. Geol. Survey No. 284, 1906, p. 134.

gravel, many of which contain enough gold to be easily seen, even when hastily examined. Mica schist, in which occur occasional thin limestone beds, forms the true bedrock, but the so-called "bedrock" on which the gold lies is in some places the schist, in others a clay streak, and in one place gravel cemented with calcite deposited by circulating waters. Part of the gold is fine, bright, and flaky; part is coarser, containing many nuggets of 5 and 10 cents, with occasional larger ones, some of which are valued as high as $20.

This description applies to a part of the beach where both the ancient stream placers of Anvil Creek and true beach placers were mined and at first were not clearly distinguished. Farther east there was no doubt about the origin of the gravel deposits, as the contributing streams were smaller and carried less débris to the sea. Beach deposits were there developed in characteristic form. In that part of the beach the pay streak had a width of 25 to 100 feet and rested in some places on bedrock, in others on gravel, and near McDonald Creek on fine sand. The upper streak is separated from the lower or "slough over" streak by a zone of barren ground, already referred to, 100 feet or more in width. It is invariably richer than the lower streak, which in places is absent. Gold is not evenly distributed throughout the old beach, for in contrast to the extraordinarily rich gravel of such claims as the Portland, May Fraction, Bessie, and others in the vicinity of the old Anvil Creek channel there are claims or parts of claims which are of little value at the present cost of mining, because although the deposits of beach gravel are continuous across them the gold is much diminished in quantity or is lacking. Such poor spots are locally known as blanks and are places where conditions were evidently unfavorable for the concentration of gold.

Blanks have been found in places where the ancient sea beat against a low cliff of bedrock and a considerable depth of water was maintained or the slope was too steep to permit the formation of the ordinary beach deposits. Places of this kind may be compared with the present shore line at Cape Nome, although no cliffs of such size as those on the cape were present along the third beach, except perhaps at its eastern end. Other blanks occur where the coastal plain was low and flat, permitting the tides and waves to sweep over a wide area. Each of these conditions is of a kind to prevent the milling and sorting of material such as goes on constantly along the present beach.

East of Nome River the third beach is only partly exposed and the auriferous deposits are of low grade compared with those west of the river. Some of it, including what was once probably the mouth of Osborn Creek, has been mined profitably. This better part undoubtedly owes its higher gold content to the presence of the stream that emptied into the ocean here. The beach deposits lie

on other gravel, and true bedrock is nowhere present. Farther east drilling indicates that the beach is less well developed. Finer gold is found there than on any other part of the beach.

In addition to the major differences in concentration of gold along the third beach, such as are due to direct contribution by streams and such as are seen in the so-called "blanks," there are many minor differences. The gold is not evenly distributed through any of the gravel. The writer was informed that in the shallow indentations, which are found here and there along the beach, a greater concentration of gold took place on the eastern than on the western side, and that in one or two places where low ridges or rolls of bedrock reached the surface and projected slightly seaward from the beach, exceptional amounts of gold were found on their western sides (fig. 12)—a position of maximum concentration corresponding to that in the indentations just mentioned. This would indicate that the distribution of gold in the gravels was influenced largely by the prevailing direction of ocean waves and currents, although it is un-

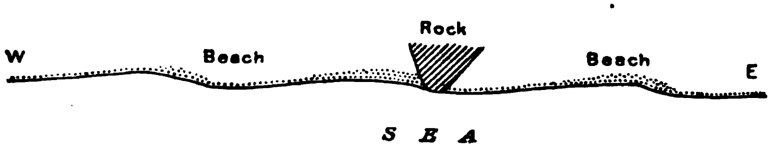


FIGURE 12.—Diagram showing concentration of gold in shallow depressions or on sides of cusps of the third beach.

doubtedly true that very rich deposits, such as occur at Little Creek and Bessie Beach between Holyoke and Bourbon creeks, are due to their nearness to the source of gold or to streams that brought it to the sea, as the character of both the gold and the gravel would point to this conclusion. On the western part of the beach the gold is on the average much coarser than at the eastern end, where it resembles in appearance and approaches in fineness that of the present beach.

The gravels of the west end, by their diversity in character and the large amount of coarse, angular stream wash they contain, show that the conditions under which they accumulated were less uniform than those prevailing farther east, and that at one time stream deposits were being laid down and at another time sea deposits.

In general, the gravel along the third beach is frozen from top to bottom, but in places there is no frost. These unfrozen areas are distributed irregularly, and their presence has never been satisfactorily explained. Their location is of great importance to the miners for two reasons. Mining can be carried on in frozen ground without such care and expense for timbering shafts, tunnels, and stopes as is necessary in unfrozen ground. Areas of unfrozen ground surrounded by frozen ground act as reservoirs for collecting surface water, which,

when tapped in mining, can be prevented from flooding the workings only by the use of pumps, and thus greatly increase the cost of recovering the gold. On the Bessie claim, near the head of Holyoke Creek, the boundary line between thawed and frozen ground was located by drilling, and care was taken not to bring the workings too close to the unfrozen area. Thawed ground is in some places overlain by frozen ground, and in one or two places is known to be underlain by it also. The presence of thawed gravel appears to be due, in part, at least, to the circulation of water through the ground, hence it seems more probable that the thawed areas have been slowly encroaching on frozen areas than that the reverse is true.

The remarkable richness of some of its gravel was such as to distinguish the third beach above all the other coastal-plain gold placers. Probably not less than $6,000,000 was produced from it in the four years 1905 to 1908. It is stated that pans of gravel could be selected from the richest spots that would yield $500 or more, and that from the May Fraction in an area 100 feet long and 15 feet wide more than $330,000 was taken, 90 per cent of which came from the bottom 3 inches of the pay streak.

In summarizing the facts regarding the third beach, it may be said that the gold deposits lie at an elevation of 70 to 79 feet above sea level but are buried under a mass of later deposits—partly marine, partly laid down by streams—ranging in thickness from 25 to 120 feet. They dip toward the south with a slope of approximately 1 foot in 10 and in some places rest on bedrock, in others on gravel, and near Nome River on fine sands.

There is a marked difference between the west and east ends of the known portions of the beach, shown by a greater quantity of angular stream wash intermingled with marine gravels and sands at the west end and a correspondingly greater quantity of fine gravel and sand at the east end. This difference is shown also by the character of the gold, which at the east end is like the gold of the present beach, but in the vicinity of Little Creek is coarse and heavy with nuggets up to $20 or more in value.

Intermediate beach.—The intermediate beach was discovered near Center Creek in the winter of 1905–6 at a point 1¾ miles from the present beach. It has been traced eastward to Dry Creek, but beyond that point its course is not determined. The beach deposits rest on a bedrock of schist with a surface sloping gently seaward and have an elevation of about 21 or 22 feet above sea level. They are thus lower than either the second or third beach and give valuable assistance in determining the relative ages of those beaches.

The total thickness of coastal-plain deposits along the known part of the intermediate beach ranges from 30 to about 70 feet, of which the beach material constitutes from 6 to 12 feet and occupies a zone

several hundred feet wide. Black graphitic schist is an important constituent of the pay gravel, which ranges from 1 to 3 feet in thickness, rests on true bedrock, and is characterized by so many fossil shells that it is sometimes called the "clam-shell beach." There is, however, considerable variety in the appearance of the beach deposits. In some places the rock fragments are not well rounded and are mixed with a large proportion of mud, in others fine sand is present, and in one place the gravel beds of the pay streak were separated by a layer of muck and were overlain by a bed of well-rounded bowlders, some of which were 2 feet long.

The gold of the intermediate beach is fine and is associated with small amounts of pyrite, arsenopyrite, and magnetite or ilmenite. Beds of ruby sand occur in smaller number than on the present and second beaches.

"Submarine" beach.—The "submarine" beach was discovered in 1907 at a point west of Snake River and nearly south of the pumping plant, where it is about one-fourth of a mile north of the present beach. It has been traced westward from that point for about 2 miles, and beach deposits thought to be its eastward continuation have been found at Dry Creek. This beach is 19 feet below sea level and forms the base of a coastal-plain section that includes from 50 to 55 feet of gravel overlain by 10 to 15 feet of muck and vegetation. The auriferous gravel has a thickness ranging from 1 to 3 feet. In some places it rests on schist bedrock; in others on older gravel deposits that fill the depressions of the undulating bedrock surface. All the deposits are frozen. This condition is a great advantage in mining, but is partly offset by the treacherous character of the roof resulting from the fact that the contact between the sand and gravel layers is a plane of weakness and permits masses of gravel to scale off and drop into the stopes. The gold is coarser than that of the other beaches and is more uniformly distributed throughout the pay gravel. Nuggets with a value as high as $10 to $12 have been found. Sulphides accompanying the gold are more abundant than in the other beaches. They include both pyrite and arsenopyrite and are associated with a little magnetite and ilmenite. Beds of ruby sand are not present in the beach, yet garnet is found in the concentrates.

The character of the gold deposits of the "submarine" beach where first discovered leads to the belief that they are not typical of concentration due to the action of surf alone, but, like those of the third beach in the vicinity of Little Creek, are in part the contributions of an old stream, possibly Anvil Creek, which have been distributed by the waves and shore currents prevalent at the place where they reached the sea.

Another so-called submarine beach, very little known as yet, is present 300 to 1,000 feet south of the one just described and 15 feet lower, or 34 feet below sea level. It lies on a false bedrock a few feet above true bedrock and 60 to 70 feet below the surface of the coastal-plain deposits. There has been no gold production from this beach, as the gold content of the gravel is small. The gold is fine and is associated with a considerable amount of heavy concentrates, consisting largely of well-formed crystals of arsenopyrite. Pyrite and chalcopyrite also are abundant, and magnetite and ilmenite are present. Garnet, just as in the inner "submarine" beach, appears in the concentrates but does not form an important part of them.

Monroeville beach.—The deposit of auriferous gravel usually referred to at Nome as the "Monroeville beach" is not a typical beach, and there is doubt as to its exact character. It lies about halfway between the intermediate and third beaches, extending in a nearly east-west direction parallel to them, and has been traced for nearly a mile between Little and Holyoke creeks. It thus lies immediately south of that part of the third beach which intersects the old channel of Anvil Creek. The pay gravel rests on bedrock at an elevation of 33 feet above sea level. It has a width from north to south ranging between 300 and 500 feet, is little more than a foot thick, and is overlain by 50 feet of frozen gravel and muck. It contains much coarse material, probably of stream origin intermingled with beach wash. This composition, together with the lack of ruby sand and of stratification, which are found in the typical beach deposits, account for the questions that have been raised concerning its character.

The gold is present in the gravel pay streak and in the 2 or 3 feet of schist underlying it, both of which are removed and put through the sluice boxes. In the richest part of this beach the gold is coarse, containing a large proportion of nuggets, but both to the east and to the west the coarseness decreases till the gold takes on the character of that usually found in the beaches. It is associated with a large amount of pyrite and arsenopyrite and a little magnetite.

There seems to be little reason to doubt that the peculiarities of this beach are due to the fact that its gold deposits are situated, just as on the third beach, at the place where beach deposits and stream deposits were intermingled and neither was developed in its usual form. Another explanation that may have some validity, although no definite evidence for it is available, is that some of the gold may be concentrated very near to its original bedrock source.

Origin of the beach placers.—It has been seen that the buried beaches differ only in minor ways from the present beach, and it is

probable that all were formed in essentially the same manner. It is also probable that the causes leading to the concentration of gold in one beach were those leading to its concentration in the others, and that the immediate source or sources of the gold were the same. There is room, however, for difference of opinion as to the manner in which the concentration took place.

Three explanations for the origin of the beach placers may be considered—(1) that they are due to concentration, by wave action, of gold widely distributed in small quantity through the tundra gravels; (2) that the gold was brought to the coast from its bedrock source by streams and then carried along the beach by waves and ocean currents; (3) that the concentration results from both the causes just mentioned acting together.

Gold is found in all the tundra gravel deposits wherever they have been tested. The amount, however, except where concentration has taken place, is too small to pay for mining under present conditions and by the methods now in use at Nome, unless dredging proves to be sufficiently economical. The gold is fine, is present in the muck as well as in the gravels, and is even reported to have been found in or on some of the ice beds. Because of the small quantity in the gravel other than the pay streak of the beaches or streams and the fact that it can not be recovered economically, few if any attempts have been made by prospectors to determine the amount present. It is estimated, however, by some of those who have put down shafts along the beaches and elsewhere that the average content is about 10 cents to the cubic yard. In places it is several times as great. These estimates were based on panning tests and may be too large, but they indicate that the tundra gravels must be considered as a source of part of the beach gold deposits.

An explanation for the concentration of gold from the coastal plain was proposed by Schrader and Brooks and was later elaborated by Brooks,[1] from whom the following is quoted:

In the "Preliminary report" Mr. Schrader and the writer advanced the theory that the gold was concentrated from the coastal plain gravels by the wave action which cut the seaward escarpment of the plain. The diagrammatic sketch which we published to illustrate this point is here reproduced [fig. 13]. In this sketch the edge of the coastal-plain escarpment is marked, and the position of the beach placers in reference to it is shown. During high storms the waves even now reach the margin of the escarpment and cut away the base of the bluff. The materials which go to make up the coastal plain are sorted by this wave action, and the heavier particles, such as the gold, sink into the sand. It is a well-known fact that this fine gold will make its way through sand for some distance, provided its passage is not interrupted by any impervious layer. This downward movement is brought about near the surface of the beach by the constant motion which is given the sand by the waves. The percolating waters

[1] Brooks, A. H., and others, Reconnaissances of the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 89.

will also help to carry the grains of gold downward. It should be noted here that the beach sand, being well drained, is not frozen in summer. In the course of its downward passage the gold finally reaches a clay layer and here becomes concentrated as it is found. There is another factor which may have accelerated the downward movements of the heavier particles. In the spring months southerly storms frequently pile up the ice on the Nome beach to a great height. When large floes are driven ashore on the shelving beach they must cause considerable movement in the underlying sands, and this motion is probably transmitted to a depth of several feet, and causes a disturbance among the grains of sand. A sort of sifting process would take place by which the heavier particles would always descend and eventually be concentrated beyond the line of movement or on impervious layers which they could not penetrate.

If we assume from our knowledge of the width and slope of the present beach that the gold in it was concentrated from a prism of gravels whose cross section is a right triangle with sides of 15 and 300 feet—that is, with an area of 250 square yards—and that the gold content of the gravels is 10 cents to the cubic yard, we get a value of

FIGURE 13.—Diagrammatic section of beach placers.

$25 to a linear yard or $43,000 to a linear mile of the beach. The gold production of the beach is over $1,000,000, all of which was obtained within a portion 20 miles long and most of which came from a portion less than 10 miles long. The valuation of $43,000 a mile is thus too small for the beach. This deficiency may be accounted for in several ways—too small a prism of gravel was used, or too small a gold content was assumed, or gold has been contributed to the beach in some other way. Finally any two or all of these variables together may have helped to produce the difference.

Again, there are places along the beach where the pay streak is said to have produced $1 to the pan or about $150 to the cubic yard. Assuming that the width of this pay streak was 20 yards, or less than one-third the average width of the beach, a value of $3,000 to a linear yard of beach is obtained. It was a matter of common observation that the gold was not distributed in anything like regular manner along the beach, and it is evident that if the beach gold were all derived from coastal-plain gravels their gold content was not disseminated at all uniformly through them, or else some other cause has operated to move the gold horizontally along the beach, so as to give

the very rich concentrations and the intermediate stretches of smaller value that exist.

The streams reaching Bering Sea near Nome—for instance, the two tributaries of Snake River, Dry and Bourbon creeks—cross the richest portion of the tundra. If with these are included Anvil Creek and Newton Gulch the list comprises the important gold-producing streams flowing south from what is known to be the chief area of mineralization of the region. These streams, more especially those crossing the tundra, derived their gold from two sources. Part was received from the bedrock of their upper portions and part is a concentration from the tundra gravels. They have fairly well-defined pay streaks corresponding more or less closely with the present stream channels. To what extent gold is carried downstream under such conditions it is perhaps impossible to state, but it is certain that much of the gold of the tundra gravels near the beach must have traveled south at least 4 miles before reaching its present resting place, and it is reasonable to suppose that streams may carry gold in their channels equally far. There can be little doubt that part of the gold, although possibly a small part, was not liberated from the inclosing quartz or schist until the fragments containing it had traveled far from their original source. Grinding by pebbles in the streams and milling by the surf may be confidently referred to as two processes by which gold is freed from the rock, and it is evident that nuggets or heavy particles of gold could be transported by water more easily as parts of pebbles or bowlders than as free metal. Fine gold is readily carried by currents of water, and its presence at a distance from its source is more easily explained than is that of coarse gold. It is possible to account for coarse gold on the present beach without proving the ability of a stream to transport nuggets in the form that they have when found, and it is believed that part of the beach gold was carried to its place directly by streams. The gold found on the sand spit between Snake River and the beach and on the lower end of Bourbon Creek bears evidence of this. It is heavy and coarse like stream gold and is altogether different from that usually found on the beach.

It has been urged that if the gold of the Nome beach had been brought to the sea by streams and then distributed along the beach by waves and ocean currents, the concentration would have taken place on only one side of the stream. It is true that there is a prevailing current along nearly all coasts, and that the mouths of the streams entering Bering Sea give evidence of such a current here that would carry material in one direction, yet we know from observation that currents set both ways along the coast at Nome and that although there is now a prevailing westerly direction of movement it is not the sole one. Aside from this consideration, it is certain

that the waves are far more effective in moving the sands and gravel of the present beach than the ocean currents, and that the direction in which they move the material depends on the direction of the winds. An interesting fact connected with this question is that fine gold and mercury are found in the top sands of the bars off the Nome beach. The mercury and possibly the gold also were carried there since mining began on the beach.

A second objection to the supposition that gold has been brought to the beach by streams is that little gold is found on the river bars. Although this is true, it is also true that both Bourbon and Dry creeks are gold bearing within a short distance of the beach, and that coarse as well as fine gold is found in Snake River only a short distance from its mouth. Part of this gold is much coarser than any found on the first or second beaches and resembles gold from such a stream as Anvil Creek far more than that from the beaches, except some parts of the third beach.

Finally, it is urged that the gold is too coarse to be carried by ocean currents, but this objection holds equally or better against the original distribution of gold through the tundra gravels, which near Bering Sea are chiefly marine.

The richest part of the present beach corresponds in position with the richest parts of the old beaches so far as they are known, also with the most productive streams—that is, it lies directly seaward from the area from which the gold is believed to be derived. It is certain that the gold of a part of the third beach, especially in the vicinity of Little Creek, was deposited near the mouth of a stream or the mouths of several streams. The character of both the gold and the gravel indicates this. On most of the third beach, however, the gold is like that of the present beach and was probably concentrated in the same way.

It seems a fair conclusion, therefore, that the beaches, both ancient and modern, have derived their gold from two immediate sources, a part having been brought to the sea by streams and a part concentrated from older gold-bearing gravels. Yet even the stream gold, it must be remembered, has been repeatedly concentrated from older deposits, the whole process forming a cycle of events which it is now impossible to trace.

GRAVEL-PLAIN PLACERS.

A number of less important placer deposits that have yielded gold apparently do not belong under any of the headings given. They do not occur as well-defined concentrations, such as are found in the stream-bench or beach placers, but as irregular accumulations disseminated through gravels, which in some places do not appear to be connected with streams or the sea. These deposits have been

called gravel-plain placers by Brooks[1] and unconcentrated placers by Collier.[2]

At some places on the coastal plain they may result from simply a local increase in the amount of gold disseminated through the gravel, yet there is a question as to whether they may properly be called unconcentrated deposits, and it seems probable that former streams may account in part for their formation. It is possible, also, that some of them may be the scattered remnants of a previous concentration similar to those found in a number of places where bench deposits or old benches have been destroyed by later streams.

Placers of this kind are small, and although one or two have yielded considerable gold, no very rich ones have yet been found. It is probable that if the origin and subsequent history of the coastal plain were fully known, these placers might be found to have an origin similar to that of the other placers of the vicinity.

About 2 miles from the coast, near the head of Peluk Creek, several thousand dollars has been taken from the coastal-plain gravels. The following section was exposed:

Section near head of Peluk Creek.

	Ft.	In.
Gravel and clay	1	6
Sandy clay and muck, with some angular gravel	5–6	
Angular gravel with clay	4	
Clay seam, "bedrock"	2	

The gold-bearing gravel rests on the clay seam and consists of angular fragments of schist with clay. Gravels under the clay were also found to carry gold but were not exploited. The gold was coarse, rough, and stained with iron. A nugget worth $1.25 was the largest found.

An attempt was made to dredge gold-bearing gravels near Cooper Gulch, about half a mile from the foothills. The largest accumulations of gold were found on clay streaks in the gravel, although a small amount is present throughout the gravel from the surface down. This locality is near the third-beach line, but its gold deposits are probably the result of stream action and not of the sea.

Gold-bearing gravels of similar character are found along the eastern slope of the Nome River valley at two or three places, but have not been visited by the writer.

DREDGING.

The scope of this paper does not include methods and costs of mining, the value of reserves, and related subjects, which belong

[1] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 81.

[2] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 166.

in the province of the mining engineer, yet so much attention has been given within the last five or six years to dredge construction, and dredging promises to play so important a part in the future development of the Nome district, that it is desirable to give a brief statement of the number of dredges now in operation and the conditions under which they work. This subject has been treated more fully from the engineer's standpoint by Gibson [1] and by Janin.[2]

The following table, giving the more important facts concerning dredges at Nome, is taken from a table compiled by Smith:[3]

Dredges built in the Nome gold field from 1905 to 1911.

Company.	Creek.	Date built.	Type or builder.	Size of buckets.	Bucket line.	Source of power.	Fuel [oil] used per day.
				Cu ft.			
Gold Beach Dredging Co.	Osborn....	1905	I. B. Hammond.......	5	Open.	Crude oil....	18 bbls.
Nome Consolidated Dredging Co.	Bourbon..	1908	E. L. Smith-Linderwood.	9	Close.	Electricity[a]	(?)
Do............	Wonder...	1908	.....do................	7	..do..	.....do......	(?)
Plein Mining & Dredging Co.	Otter.....	1910	Risdon...............	3½	Open.	Crude oil....	13 bbls.
Saunders Dredging Co.	Saunders..	1910	(?).....................	3½	Close..	Distillate....	200 gals.
Arctic Gold Dredging Co.	.....do....	1910	Union Iron Works....	2½	..do..	.....do......	160 gals.
Sioux-Alaska Mining Co.	Moss......	1910	.....do..............	2½	..do..	.....do......	Do.
Julien Dredging Co.	Osborn....	1911	Union Construction Co.	2½	..do..	.....do......	190 gals.
Nome Consolidated Dredging Co.[b]	Wonder...	......	....	10	....	Electricity..	

[a] Power generated from oil. [b] In course of construction.

Dredging in the Nome district and in Alaska generally is conducted under adverse conditions not encountered in warmer climates. The working season is a little longer than that for the simpler surface methods of mining, as the machinery can be protected against the cold to a certain extent. Experience at Nome has shown that dredging can begin in the later part of June and continue till late in October or even into November. The efficiency of the dredge is less in the early part of the season, however, than at the close, as the frost is not all out of the ground when operations begin. Frozen ground is one of the chief obstacles to dredging in the North, for a dredge will not work in such ground, and in order that mining may be carried on some means must be provided for thawing the gravel. Steam points are used for this purpose in the Yukon region but have not been employed at Nome, where all the dredging has been done in unfrozen gravel. Thawing would add to the cost of dredging, for

[1] Gibson, T. M., Gold-dredging industry on Seward Peninsula: Min. and Sci. Press, vol. 104, 1911, pp. 45–48.

[2] Janin, Charles, Gold dredging in Alaska and the Yukon: Min. Mag., vol. 6, 1912, pp. 45–48.

[3] Smith, P. S., Notes on Seward Peninsula: Bull. U. S. Geol. Survey No. 520, 1912, p. 342.

it would increase the consumption of fuel, already a large item of expense.

Coal, crude oil, and distillate are the forms of fuel used in generating power for the Nome dredges. Even those driven electrically depend on an engine consuming fuel oil. No use has yet been made of water power in this district, although such power is at hand and would have been employed before this time if litigation over the water rights had not prevented.

One of the most important considerations connected with the installation of dredges concerns the character of the gravel containing the gold and the bedrock on which it lies. Gravels in which many large bowlders are present, such as are common in the highly glaciated areas of much of Alaska, are unsuited to dredging operations, as is also gravel resting on a hard, uneven bedrock where the gold is not distributed through the gravel but lies principally on the bedrock and in its cavities.

Some of the deposits of stream gravel at Nome are suitable for dredging and are being handled profitably in this way. The gravel of the larger streams, like Snake and Nome rivers, and of smaller ones crossing the coastal plain does not contain many large bowlders. The material composing it is such as can be handled by a dredge when it is not frozen. There are many bowlders in parts of the coastal-plain deposits and others are scattered over its surface. They are of glacial origin and were either deposited by the glaciers or brought by floating ice. Bowlders of this kind have found their way into the stream gravels and at times give some trouble, but they have not proved to be a serious obstacle in mining, although they undoubtedly will cause some difficulty if dredging is attempted in some of the coastal-plain deposits. In those stream deposits whose character is favorable to dredging probably more difficulty will arise because of frozen ground than because of bowlders.

The Nome region offered a new field for dredging and has attracted the attention of dredge builders. New problems were encountered, and some of them have been solved. The early attempts at dredging met with little success, because the conditions were not understood and dredge construction had not reached its present efficiency, but the success of the past few years has placed dredging at Nome on a secure basis.

LODE DEPOSITS.

GENERAL FEATURES.

The principal useful metals that have been found on Seward Peninsula are gold, silver, lead, tin, bismuth, antimony, tungsten, copper, and mercury. These metals, either in their native state or in combi-

nation with other elements, have been found in their bedrock source as well as in the gravel deposits resulting from rock weathering and erosion. Gold is the only one of them whose lode deposits have yet been mined profitably. Tin is found in the gravel deposits of many widely separated localities. Tin-bearing lodes that have attracted much attention from capitalists were discovered in the western part of the peninsula in 1903, but the mining of these lodes is not yet an established industry, although some small shipments of lode tin as well as of placer tin have been made. Silver-bearing galena was discovered many years ago on Omalik Creek, a tributary of Fish River, in a lode deposit usually referred to as the "Omalik mine." Although several attempts have been made to develop this property, they have so far led to no important results. Among the other metals tungsten, antimony, bismuth, and possibly copper have been found in sufficient amount to justify the expectation of some future development. There is, however, little reason to attach much commercial importance to the presence of mercury. It occurs as the mineral cinnabar in the gravel deposits of the Council region and in small veins in the schist, but its amount is not great. Besides the metals enumerated the mineral graphite gives promise of commercial importance. It is present at several localities in the Kigluaik Mountain area, and small shipments have been made from places on the north side of the range, not far from Teller.

All the metals named except mercury occur in the Nome and Grand Central quadrangles. Gold is, of course, the most important, and it is the most widespread. Bismuth and antimony have attracted some attention, and tungsten, in the form of scheelite, may, perhaps, take a more important place among the mineral resources than it has hitherto held.

GOLD.

There is scarcely a stream within the plateau area of the Nome and Grand Central region whose gravel deposits do not yield gold in quantities ranging from a few colors to amounts great enough to pay for commercial exploitation. This is true also of most of the other streams of Seward Peninsula and demonstrates the widespread distribution of gold in the metamorphic rocks. Few of the streams of the Kigluaik and Bendeleben mountains have produced gold, but the reason for this may, perhaps, lie in the conditions resulting from glaciation, the character of the surficial accumulations, and the difficulty of prospecting, as much as in the gold tenor of the gravel.

Two facts stand out before one who carefully studies the distribution of the gold-bearing surficial deposits—first, the widespread occurrence of gold in small amounts throughout the region; and, second, the comparatively small size and number of the areas producing placer gold in considerable amount. These facts appear

to lead to only two conclusions—that gold is present in small quantity in practically all the older rocks, and that in a few places, for some unknown reason, this gold content was very greatly increased. The increase is relative, and does not necessarily imply that the original deposit was of extraordinary value, for it is evident that a very rich placer can be formed by the weathering of a large amount of rock, with small gold content. The quantity of material removed by the streams during the formation of the present topography of the Nome region is enormous, and the gold contained in even the richest parts may have borne only an insignificant proportion to the original mass of rock. Yet it is not intended to imply that the rich placers of the Nome region are derived wholly from original deposits, too low in gold content to be valuable as mining properties, or that no lodes of commercial importance will be discovered. Although such lodes may not be found, the experience of many other placer camps goes to show that rich placers are commonly situated in regions where lode mining is eventually developed.

In the Nome region deposits of gold in bedrock, as distinguished from deposits of placer gold, may be broadly classified as disseminated deposits and vein deposits. Under the first head should be included those deposits in which mineralization is not confined to well-marked fault, joint, or similar fracture planes, but has taken place in the schist as a result of the circulation of mineral-bearing solutions through it, principally in minute openings, along cleavage planes and elsewhere, produced during the processes of metamorphism and deformation. The vein deposits are those in which mineralization took place in or along fracture planes, most of which are fairly well defined. They are accompanied by a notable amount of gangue material, consisting chiefly of quartz, but locally including some other minerals, such as calcite. The distinction between the two classes of deposits is, in a measure, arbitrary, depending in some examples on size rather than on fundamental differences, for it can hardly be doubted that both classes may be produced by the same geologic processes, however unlike the form of the channels through which circulation takes place. The auriferous quartz veins might be further subdivided into those in which free gold is unaccompanied by other metals and those in which it is associated with various sulphides, as pyrite, arsenopyrite, molybdenite, and stibnite. This distinction has been made by Smith[1] largely as a result of his work near Solomon, but owing to the lack of detailed knowledge concerning many of the gold-bearing veins near Nome, it is perhaps undesirable to attempt to classify them on this basis.

[1] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey, No. 345, 1908, p. 230.

Small gold-bearing veins have been found near many of the gold placers, where bedrock was exposed originally, or was uncovered during mining operations, but at present no veins of proved commercial value are known in the Nome district. An account of the occurrence and character of the veins has been given. (See pp. 34–36.) Quartz veins, calcite veins, and veins consisting of quartz, chlorite, and feldspar are those most common in the region. The quartz veins may be divided into at least two classes, which, however, are not entirely distinct from each other. One class includes small veins, the largest only a few inches thick, stringers, and lenses, which in most places conform to the cleavage of the inclosing rock, though in others they intersect the bedding and cleavage. These veins are of small linear extent, and are not uncommonly folded and crushed. Most of them were deposited either before the schists and limestones were folded, or, as is most probable, while the folding was taking place. They are the typical veins of the region, and in many places are well mineralized. They are seen on Anvil, Glacier, and Rock creeks, on Snow and Pioneer gulches, and in other localities.

The second class includes, besides many small veins, large veins, or irregular masses of quartz, most of which are found in localities that plainly have been greatly disturbed by later movements in the rocks. Although some such masses are 20 feet or more thick, nearly all are limited in longitudinal extent to a few times their thickness, and are much crushed and faulted. The weathered surface is milky white, and only on fracture planes that have not been exposed does a stain of iron oxide appear. The veins contain very little pyrite, so that cavities due to the decomposition of this mineral are not so common as they are in many of the smaller veins.

After a detailed study of the Solomon and Casadepaga district, only a short distance east of the area under consideration, Smith[1] summarized as follows his conclusions concerning the veins which he found there:

> The occurrence of veins has already been noted, and their division into three main classes has been made. These classes were called the older and the younger quartz veins and the calcite veins. The latter class is of no importance from an economic standpoint, and it therefore requires no further attention.
>
> The older quartz veins are sheared, squeezed, and in many places are recrystallized, so that all original structure has been lost, and the veins appear as lenses or knotted quartz bunches in the contorted schists. Some of these bunches are evidently older than the cleavage, for that structure has been forced to wrap around them. In these veins there are sometimes traces of metallic minerals, such as iron pyrite, and the presence of gold has been noted

[1] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey, No. 433, 1910, pp. 139–140.

in assays made by earlier collectors. The veins, however, are so deformed that it seems hopeless to mine them.

The younger quartz veins are somewhat deformed, but are not so completely sheared and contorted as are the older ones, having been shattered and smashed rather than knotted and recrystallized. In some places these veins show but slight evidence of metallic mineralization, but at others they contain abundant sulphides. In some of these later-formed veins the metallic minerals are sulphides of copper, in others they are arsenopyrite, and in still others they are iron pyrite. Whether the veins show other metallic minerals or not, they almost always contain a little gold in the native state.

It will be noticed that in this summary no mention is made of quartz-feldspar veins. This omission is not due to the absence of such veins in that district, but to their subordinate importance. With this exception it is seen that the subdivision of veins given by Smith may be applied to the Nome and Grand Central region, the greater number of quartz-feldspar veins here being probably in considerable measure a local feature.

Brooks[1] has recently emphasized the importance of examining the vicinity of limestone and schist contacts for gold-bearing lodes and for placer-gold deposits. He points out that many contacts such as these are loci of weakness in the strata, where movement takes place and where there is greater opportunity for the circulation of mineral-bearing waters and consequently for the formation of veins. He also draws attention to the fact that most of the important placer areas are in regions where limestone and schist occur.

Massive limestones are found in the southern part of the mineralized area of Anvil and Glacier creeks, and thinner beds occur in the ridge between the two streams. To the northwest, however, their number decreases, and here some of the greatest mineralization is seen. It is not evident in this particular place that the presence of limestone was essential to the formation of mineral deposits, and, in fact, it would be difficult to prove that the limestone and schist contacts on the southeast are more highly mineralized than the schists away from the contacts, but the occurrence of nearly all the placer-gold deposits of the peninsula in areas where limestone is found suggests a relationship between the formation of such deposits and the limestone.

Gold can be seen in some of the quartz veins of the Nome district. and assays have shown its presence in many more. Gold is not confined, however, to quartz veins alone; free gold occurs in calcite veins also. Gold-bearing calcite veins are present on the divide between Anvil and Glacier creeks, where several shafts were sunk without revealing an important ore body. Near by, quartz veins in the schist carry a small amount of gold and a little molybdenite. Two or three veins of this kind are exposed near the wagon road leading

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 122.

over the hill to Glacier Creek. One of these varies in thickness from 1 to 2½ feet and is included between schist and a thin overlying bed of limestone. It can be traced for about 100 feet along the surface.

Northwest of this point, on Snow Gulch, a number of small iron-stained quartz veins cut the schist of the creek bed. Picked specimens from quartz veins on Glacier Creek near the mouth of Snow Gulch yielded about $9 a ton in gold when assayed. The inclosing schist is highly impregnated with pyrite and contains gold also.

Attention has previously been drawn to the mineralized area between Glacier and Rock creeks and the association of sulphides occurring there. The schist is filled with a great number of small quartz stringers containing pyrite and is itself impregnated with the same mineral to such an extent that the deeply weathered surface rock is strongly colored by the oxidation products. A mixture of the sulphides of lead, arsenic, antimony, and copper is associated with the pyrite and for a while was thought to be a new mineral. The quartz stringers carry free gold and are so numerous that some attempts have been made to mine them.

A large amount of highly mineralized quartz is present in schist exposures south of Good Luck Gulch. The quartz is much crushed and in general occurs as stringers, although at one place a mass 4 or 5 feet wide is exposed in a small outcrop. A prospect hole shows much rotten iron-stained quartz. The schist also is filled with iron oxide, in which some pyrite still remains. Panning shows the presence of gold.

Several quartz veins, the largest of which is about 5 inches thick, occur near the mouth of Boulder Creek. Assay values of $3 to $4 a ton in gold were obtained from samples taken here.

On Pioneer Gulch the best ground of the residual placers occurs just below a number of small quartz stringers cutting the schist bed-rock. One of these stringers 3 inches thick showed considerable free gold. Similar occurrences are known in other parts of the region, but nowhere has the number or size of the mineralized veins been sufficiently great to constitute an ore body.

Near the head of Goldbottom Creek are auriferous veins, one of which has received more attention than most of those already mentioned. It is near the contact between the massive limestone beds of Mount Distin on the east and the schist underlying the limestone on the west. The country rock is black graphitic slate, much jointed and cut by veins and stringers of quartz belonging to the later system of veins. Movement in the slate, which took place during the adjustment to disturbing forces, gave rise to numerous smooth slickensided surfaces. The vein quartz is milky white to glassy, with darker bands here and there. Locally there is a little sulphide mineralization, but for the most part the veins appear to belong to that class

in which the gold occurs free in the quartz. The property is equipped with a small stamp mill and machinery for crushing the ore. Water is provided by a ditch about a mile long. It seems probable that the shattered condition of the country rock would offer some difficulties to following the ore, but the results of operations during the last year or so have not been learned.

Mining operations along Anvil Creek have disclosed auriferous veins at several places. Near Perkinsville many small quartz veins, from 8 to 10 inches thick, cut black chlorite schist. Most of the veins follow the schistosity of the rock, but some of them cross it. They are slightly folded and much crushed. A little iron pyrite is scattered through them, and assays show a small content of gold.

Two small openings were made a number of years ago on quartz veins near the head of Anvil Creek. Both are in black quartzitic schist much crushed and fractured. The quartz is slightly iron stained, and a little gold is reported, but no work has been done on the veins recently.

All the localities that have been mentioned are within the Snake River drainage basin, the area that contains the richest gold placers discovered in the Nome region. The list of mineralized veins and zones includes, however, other localities. Such deposits are known at the head of Dry Creek and on Newton Gulch, where they have received some attention with a view to development. A quartz vein on Osborn Creek shows gold associated with iron and copper sulphides. The vein is near the contact of a greenstone intrusion in schist. Only a little work has been done on it. Gold-bearing veins are known also on Banner Creek, Stewart River, and Buffalo and Hudson creeks. Mineralized quartz veins have been found on an eastern tributary of Grand Central River, where they cut black graphitic schist and contain a small amount of pyrite.

Although none of the operations on gold veins of this district appear to be commercially successful, they nevertheless have lent some aid to an understanding of the types of ore bodies likely to be met with.

Experience so far points toward the probability that, if commercial ore bodies are found, they will be in the form of small veins and mineralized zones in the schist. No well-defined and continuous belts of this kind have yet been discovered. There are restricted areas, however, where auriferous deposits are more widely developed than in the remaining parts of the region, and in general these correspond in location with the placer-gold areas. It was this fact that early led the workers in this region to the conclusion that the placer gold has its source in veins and impregnated beds, which occur close to the present location of the placers.[1]

[1] Brooks, A. H., Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900; Special publication U. S. Geol. Survey, 1901, p. 142.

BISMUTH.

It has been known for a number of years that bismuth is present on Charley Creek, a tributary to Sinuk River from the south. It was first found in the sluice boxes at the lower end of the creek, and later the float was discovered farther up and traced to its source. On the east branch of Charley Creek at a point about 1,000 feet from the forks and at an elevation of 950 feet above sea level, two parallel quartz veins appear near the stream bed and have been found to carry the bismuth. These two veins are about 12 inches and 8 inches in thickness and are separated by 16 to 18 inches of schist. They occur in strike joints dipping 50° to 60° and may be traced on the surface for only a short distance because of the covering of loose slide rock. At one place they are offset about 8 to 10 inches by a small fault. The proportion of bismuth seen in the veins is small, but some bowlders found in the stream below show a larger amount. Up to the present time little has been done toward prospecting the veins.

ANTIMONY.

A quartz vein carrying the sulphides of iron and antimony was found on Manila Creek in 1905. It crops out on a hill slope west of the upper end of the creek, and as traced by surface float has a length of about 3,000 feet. Its elevation above sea level is approximately 800 feet at the southwest end and 1,600 feet at the northeast end. At the surface it appears to dip moderately to the northwest. The surface float is quartz containing bunches and irregular streaks of stibnite scattered here and there or running through it. It is stained with oxidation products from stibnite and pyrite.

A prospect-hole incline was started on the vein in 1906. In 1907 an adit 315 feet long had been driven cutting the vein and showing it to have a thickness of 3 feet at that place. Since then considerable work has been done, and shipments of ore have been made. The antimony content of the ore where the vein is crosscut is less than at the surface, but the decrease is compensated for by an increase in gold. Specimens of ore from the vein in the adit show a mixture of gray quartz and antimony containing a notable amount of free gold. The quartz is crushed, and the spaces between fragments are filled with stibnite. Furthermore, tiny veins of stibnite cut the larger pieces of quartz. The gold appears to be more closely associated with the quartz than with the stibnite, and may have been deposited earlier, but this inference requires further evidence before it can be stated positively. A number of other minerals are reported from this property, but do not appear in the specimens examined by the writer.

Veins carrying stibnite occur on the west side of Anvil Creek a short distance above Specimen Gulch and have been described

by Smith.[1] The veins were prospected by a number of holes about 25 or 30 feet above the creek, and these showed that the schist had undergone much dislocating and shearing, which produced fractures that had later been filled with stibnite and other minerals. Some of the veins reach a thickness of 18 inches, but most of them are thinner. The stibnite occurs in rather massive aggregates for the most part but here and there appears as radiating and lath-shaped crystals of nearly perfect crystalline form, showing that it must have been deposited after the close of the period of dynamic disturbances that affected the country rock. The economic importance of this fact is that such veins give greater promise of freedom from the faulting and dislocation that detract from the value of the ore bodies.

Stibnite is reported also from Osborn Creek, Goldbottom Creek, and Last Chance Creek, but the deposits at these localities have not been examined by members of the Geological Survey.

TUNGSTEN.

Tungsten occurs in the Nome region in the form of scheelite, the tungstate of calcium. It is a heavy white mineral and is found in many of the streams. Because of its weight it remains in the sluice boxes or pan and causes some trouble in cleaning the gold. Scheelite is also found associated with quartz in small veins in the schist, but its principal source is the gold-bearing gravel. Until recently the market price of tungsten has been so small that the scheelite has not been taken from the sluice boxes, but the present demand for the metal is so great that even small quantities may be profitably collected.

Tungsten is used in the manufacture of tungsten steel, in incandescent lights, and for various other purposes.

COPPER.

Copper deposits have not attracted much attention in the Nome district, as those already known have not yet proved to be of commercial importance. Two localities where copper minerals have been found are described by Smith,[2] who furnishes the following account of them.

The most promising locality is on the ridge between Copper and Dickens creeks at the head of Nome River. It lies within the area occupied by schist and limestone of the Nome group, and the geologic relations of the rocks are obscured by complicated structure and by scarcity of outcrops. The rocks are principally schist but include thin beds of limestone. Two types of schist are present. One of

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[1] Smith, P. S., Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, p. 282.

[2] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey No. 345, 1908, pp. 240–242.

these is silvery gray and consists chiefly of quartz with which is associated muscovite and chlorite. The other is dark greenish and contains many crystals of feldspar together with a little amphibole. This second schist is believed to be an altered igneous rock of basic character. All these rocks have a low dip to the northeast. There is a small mass of intrusive granite in the schist about a mile north of this locality.

The copper minerals are found in a narrow belt of white limestone overlain by green schist and underlain by green and gray schists. An inclined shaft was sunk in this limestone and gives the best information concerning the ore body. Smith[1] described the occurrence of copper at this locality as follows:

The character of the vein and the distribution of the metals in it are peculiar. All over the surface are numerous blocks of limestone stained with a little malachite, but in the upper portion the vein shows mainly galena. Specimens from this upper portion show numerous drusy cavities, and the appearance is that of a replaced limestone. In every fragment several small quartz veins are visible. The ore is almost entirely galena with only a small amount of copper carbonate and practically no copper sulphide. An assay of picked specimens made by the owners is reported to have yielded 15 per cent of copper and 20 per cent of lead, with a rather high silver and low gold content.

In the breast there seems to be a nearly vertical fissure, which shows for some distance in the inclined shaft. From this fissure a good deal of bornite, practically unmixed with any other minerals except galena, has been won This vein seems to pinch out 2 feet or so below the roof, and the bornite is absent from the rest of the underground workings. Near the floor of the incline there is a quartzitic rock which looks much like a replaced limestone. This quartzite contains a band about 8 inches thick of copper sulphides and carbonates mixed with quartz. The sulphides are mainly chalcopyrite, and both the carbonates, azurite, and malachite are present. In addition to the main stringers already described, some ore is scattered throughout the breast, but it is too disseminated to allow profitable extraction.

The sulphides in the lower part of the mineralized belt occur nearly parallel with the stratification of the limestone. Nowhere in the underground workings was schist seen, but from the evidence already cited it seems probable that the contact of the schist would be found a short distance below the floor of the incline.

Other prospect holes in the near vicinity show evidences of copper. About one-third of a mile above the mouth of Copper Creek an adit was run in 25 to 30 feet on some stringers of copper ore at a schist and limestone contact but was finally abandoned.

The second locality where copper minerals have been found is on Dexter Creek. Assays are reported to show the presence of 4 per cent of copper, but the ore is probably more valuable for gold than for copper.

GRAPHITE.

Graphite is abundant in some of the black schist beds belonging to the Nome and Kigluaik groups and gives them their characteristic

[1] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull U. S. Geol. Survey No. 345, 1908, p. 241.

color but is not known in a form to make it of economic importance within the Nome and Grand Central quadrangles. Just north of the Grand Central area, however, in the headwater areas of Grand Central River and Windy Creek (Pl. VII, p. 20), especially in the vicinity of the divide between these two streams, are graphite deposits of considerable size. Their occurrence, as well as that of graphite on the north side of the Kigluaik Range west of Cobblestone River, has been known for a long time, but only recently have they received especial attention from prospectors.

A sharp ridge made up of biotite schist striking east and west and intruded by dikes and sills of coarse granitic rock or pegmatite rises on the south from the saddle between the Grand Central and Windy Creek. Some of the schist is highly graphitic, the graphite appearing as abundant small scales on the cleavage surface and much of it not being distinguishable on casual examination from flakes of biotite. Locally graphite is segregated in beds or much flattened lenticular masses that conform in direction with the schist cleavage and reach thicknesses of 6, 8, or even 18 inches. These beds include thin layers of schist containing numerous large garnets and much quartz. The raw graphite found at this place is heavier than the higher grades of graphite, owing to its included quartz.

The sills and dikes of pegmatite cutting the schist also contain graphite, which is associated with them in such a way as to suggest a close relationship between the intrusives and the graphite. Graphite appears to be an original mineral in the pegmatite as well as to be associated with it in the schist. At one place about 8 inches of solid graphite is included between a pegmatite sill and the overlying schist. The steep slopes of the mountain are strewn with graphite fragments, which, owing to the fact that they are much lighter in weight than either the schist or the pegmatite, appear more abundantly on the surface, especially in gullies where water has brought about a rough sorting. One block, with dimensions of approximately 7 feet, 6 feet, and 30 inches, consists of about equal thicknesses of schist and apparently almost pure graphite.

The graphite-bearing schist extends eastward beyond the east fork of Grand Central River and westward across Windy Creek and the head of Cobblestone River to the region south of Imuruk Basin, in which the graphite is even more extensively developed than in the locality described and from which a number of commercial shipments have been made.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. $1.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

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Alaska coal and its utilization, by A. H. Brooks. In Bulletin 442, 1910, pp. 47–100.

*The possible use of peat fuel in Alaska, by C. A. Davis. In Bulletin 379, 1909, pp. 63–66. 50 cents.

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Mineral resources of Alaska, by A. H. Brooks. In Bulletin 394, 1909, pp. 172–207.
*Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 362 pp. 35 cents. Abstract in *Bulletin 259, 1905, pp. 32–46. 15 cents.
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*The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall. Professional Paper 15, 1903, 71 pp. Contains map of Prince William Sound and Copper River region; scale, 12 miles=1 inch. 30 cents.
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*Placer mining in the Fairbanks and Circle districts, by C. E. Ellsworth. In Bulletin 520, 1912, pp. 240-245. 50 cents.
*Water supply of the Fairbanks, Salchaket, and Circle districts, by C. E. Ellsworth. In Bulletin 520, 1912, pp. 246-270. 50 cents.
*The Rampart and Hot Springs regions, by H. M. Eakin. In Bulletin 520, 1912, pp. 271-286. 50 cents.
*The Ruby placer district, by A. G. Maddren. In Bulletin 520, 1912, pp. 287-296. 50 cents.
*Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River, by L. M. Prindle and J. B. Mertie, jr. In Bulletin 520, 1912, pp. 201-210. 50 cents.
The Bonnifield region, Alaska, by S. R. Capps; including geologic and topographic reconnaissance maps. Bulletin 501, 1912, 162 pp.
A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp.
A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle; with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith. Bulletin 525, 1913, 220 pp.
The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp.
A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle. Bulletin 538. (In preparation.)
The Iditarod-Ruby region, Alaska, by H. M. Eakin, with geologic and topographic reconnaissance maps. Bulletin ——. (In preparation.)

Topographic maps.

Fortymile quadrangle; No. 640; scale, 1: 250,000; by E. C. Barnard. Price, 10 cents a copy or $3 for 50.

Fairbanks quadrangle; No. 642; scale, 1: 250,000; by T. G. Gerdine, D. C. Witherspoon, and R. B. Oliver. Price, 20 cents a copy or $6 for 50.

Rampart quadrangle; No. 643; scale, 1: 250,000; by D. C. Witherspoon and R. B. Oliver. Price, 20 cents a copy or $6 for 50.

Fairbanks district; No. 642A; scale, 1: 62,500; by T. G. Gerdine and R. H. Sargent. Price, 20 cents a copy or $6 for 50.

*Yukon-Tanana region, reconnaissance map of; scale, 1: 625,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. 35 cents. Not published separately.

*Fairbanks and Birch Creek districts, reconnaissance maps of; scale, 1: 250,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. 35 cents. Not issued separately.

Circle quadrangle, Yukon-Tanana region; scale, 1: 250,000; by D. C. Witherspoon. Price 50 cents a copy. Also contained in Bulletin 295.

SEWARD PENINSULA.

*A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900, by A. H. Brooks, G. B. Richardson, and A. J. Collier. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 180 pp. 50 cents.

*A reconnaissance in the Norton Bay region, Alaska, in 1900, by W. C. Mendenhall. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 38 pp. 50 cents.

*A reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. Professional Paper 2, 1902, 70 pp. 30 cents.

*The tin deposits of the York region, Alaska, by A. J. Collier. Bulletin 229, 1904, 61 pp. 15 cents.

*Recent developments of Alaskan tin deposits, by A. J. Collier. In Bulletin 259, 1905, pp. 120–127. 15 cents.

*The Fairhaven gold placers of Seward Peninsula, by F. H. Moffit. Bulletin 247, 1905, 85 pp. 40 cents.

The York tin region, by F. L. Hess. In Bulletin 284, 1906, pp. 145–157.

Gold mining on Seward Peninsula, by F. H. Moffit. In Bulletin 284, 1906, pp. 132–141.

The Kougarok region, by A. H. Brooks. In Bulletin 314, 1907, pp. 164–181.

*Water supply of Nome region, Seward Peninsula, Alaska, 1906, by J. C. Hoyt and F. F. Henshaw. Water-Supply Paper 196, 1907, 52 pp. 15 cents.

Water supply of the Nome region, Seward Peninsula, 1906, by J. C. Hoyt and F. F. Henshaw. In Bulletin 314, 1907, pp. 182–186.

The Nome region, by F. H. Moffit. In Bulletin 314, 1907, pp. 126–145.

Gold fields of the Solomon and Niukluk river basins, by P. S. Smith. In Bulletin 314, 1907, pp. 146–156.

Geology and mineral resources of Iron Creek, by P. S. Smith. In Bulletin 314, 1907, pp. 157–163.

The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin 328, 1908, 343 pp.

*Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin 345, 1908, pp. 206–250. 45 cents.

*The Seward Peninsula tin deposits, by Adolph Knopf. In Bulletin 345, 1908, pp. 251–267. 45 cents.

*Mineral deposits of the Lost River and Brooks Mountain regions, Seward Peninsula, by Adolph Knopf. In Bulletin 345, 1908, pp. 268–271. 45 cents.

*Water supply of the Nome and Kougarok regions, Seward Peninsula, in 1906–7, by F. F. Henshaw. In Bulletin 345, 1908, pp. 272–285. 45 cents.

*Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp. 25 cents.

Geology of the Seward Peninsula tin deposits, by Adolph Knopf. Bulletin 358, 1908, 72 pp.

*Recent developments in southern Seward Peninsula, by P. S. Smith. In Bulletin 379, 1909, pp. 267–301. 50 cents.

*The Iron Creek region, by P. S. Smith. In Bulletin 379, 1909, pp. 302–354. 50 cents.

*Mining in the Fairhaven precinct, by F. F. Henshaw. In Bulletin 379, 1909, pp. 355–369. 50 cents.

*Water-supply investigations in Seward Peninsula in 1908, by F. F. Henshaw. In Bulletin 379, 1909, pp. 370–401. 50 cents.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, by P. S. Smith. Bulletin 433, 1910, 227 pp.
Mineral resources of the Nulato-Council region, by P. S. Smith and H. M. Eakin. In Bulletin 442, 1910, pp. 316–352.
Mining in Seward Peninsula, by F. F. Henshaw. In Bulletin 442, 1910, pp. 353–371.
Water-supply investigations in Seward Peninsula in 1909, by F. F. Henshaw. In Bulletin 442, 1910, pp. 372–418.
A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, by P. S. Smith and H. M. Eakin. Bulletin 449, 1911, 146 pp.
*Notes on mining in Seward Peninsula, by P. S. Smith. In Bulletin 520, 1912, pp. 339–344.
Geology of the Nome and Grand Central quadrangles, Alaska, by F. H. Moffit. Bulletin 533, 1913, 140 pp.
Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology, by P. S. Smith, and a description of methods of placer mining, by Alfred H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp.

Topographic maps.

The following maps are for sale at 10 cents a copy or $3 for 50:

Casadepaga quadrangle, Seward Peninsula; No. 646 C; scale, 1:62,500; by T. G. Gerdine.
Grand Central quadrangle, Seward Peninsula; No. 646 A; scale, 1:62,500; by T. G. Gerdine.
Nome quadrangle, Seward Peninsula; No. 646 B; scale, 1:62,500; by T. G. Gerdine.
Solomon quadrangle, Seward Peninsula; No. 646 D; scale, 1:62,500; by T. G. Gerdine.

The three following maps are for sale at 50 cents a copy or $15 for 50:

Seward Peninsula, northeastern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, northwestern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, southern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, southeastern portion of, topographic reconnaissance of; scale, 1:250,000. Contained in Bulletin 449. Not published separately.

NORTHERN ALASKA.

*A reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. Professional Paper 10, 1902, 68 pp. 30 cents.
*A reconnaissance in northern Alaska across the Rocky Mountains, along the Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901, by F. C. Schrader and W. J. Peters. Professional Paper 20, 1904, 139 pp. 40 cents.
*Coal fields of the Cape Lisburne region, by A. J. Collier. In Bulletin 259, 1905, pp. 172–185. 15 cents.
*Geology and coal resources of Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp. 15 cents.
The Shungnak region, Kobuk Valley, by P. S. Smith and H. M. Eakin. In Bulletin 480, 1911, pp. 271–305.
The Squirrel River placers, by P. S. Smith. In Bulletin 480, 1911, pp. 306–319.
*Geologic investigations along the Canada-Alaska boundary, by A. G. Maddren. In Bulletin 520, 1912, pp. 297–314. 50 cents.
*The Alatna-Noatak region, by P. S. Smith. In Bulletin 520, 1912, pp. 315–338. 50 cents.
The Noatak-Kobuk region, by P. S. Smith. Bulletin 536. (In preparation.)

Topographic maps.

*Fort Yukon to Kotzebue Sound, reconnaissance map of; scale, 1:1,200,000; by D. L. Reaburn. Contained in Professional Paper 10. 30 cents. Not published separately.
*Koyukuk River to mouth of Colville River, including John River; scale, 1:1,200,000; by W. J. Peters. Contained in Professional Paper 20. 40 cents. Not published separately.

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DEPARTMENT OF THE INTERIOR

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THE YENTNA DISTRICT

ALASKA

BY

STEPHEN R. CAPPS

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CONTENTS.

ILLUSTRATIONS.

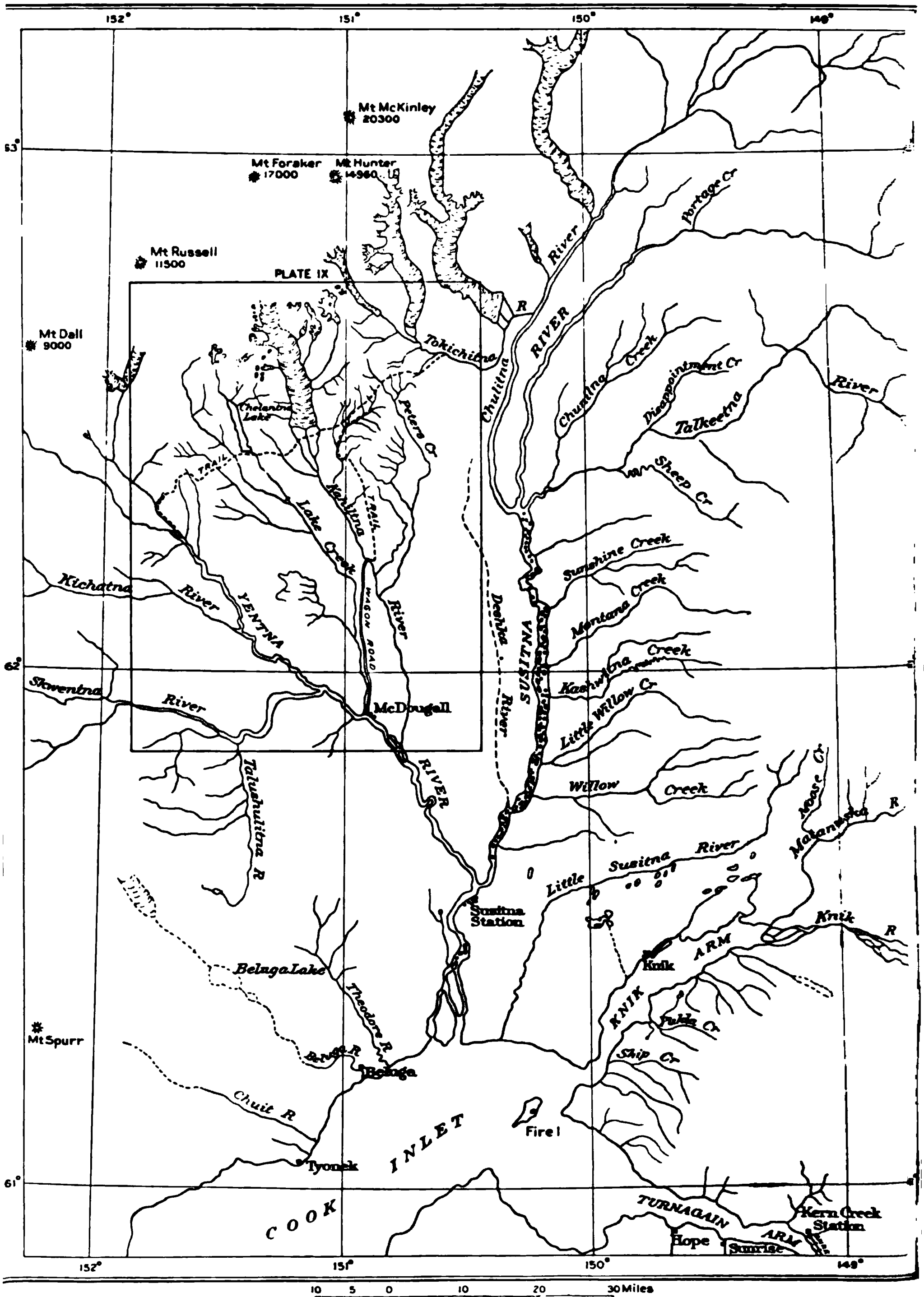
PREFACE.

By Alfred H. Brooks.

The several exploring expeditions which have traversed the Susitna basin since 1898 have determined its larger geographic and geologic features. Some areal mapping has also been done in the eastern part of the basin. Up to 1911, however, but little was known of the geology and mineral resources of the western part of the basin, including the Yentna placer district, which has made an annual gold output since 1905. The investigation the results of which are here set forth was undertaken as a part of the general plan to survey the productive mining districts as rapidly as funds permitted.

In the course of a very brief field season Mr. Capps has been able not only to map the larger stratigraphic units of the district but also to study in detail most of the occurrences of auriferous gravels. An important result of this investigation is the determination of the relations of the gold placers of Cache Creek to the recent physiographic history, including the advance and retreat of the ice sheet. Mr. Capps has also obtained evidence of the Tertiary age of the gravel sheet which overlies the Eocene beds of the region. These gravels were formerly regarded as Pleistocene. This affords additional evidence of the Tertiary age of the Nenana gravel in the Bonnifield district,[1] located on the north side of the Alaska Range. The assignment to the Tertiary instead of to the Quaternary of the heavy gravels which mantle the foothills on both sides of the Alaska Range will necessitate considerable change in the published interpretations of the physiographic history of central Alaska.

[1] Capps, S. R., The Bonnifield region: Bull. U. S. Geol. Survey No. 501, 1912, pp. 32-34.



SKETCH MAP OF THE SUSITNA BASIN, INCLUDING THE YENTNA DISTRICT.

THE YENTNA DISTRICT, ALASKA.

By STEPHEN R. CAPPS.

LOCATION AND AREA.

The Yentna district received its name from Yentna River, the largest tributary of Susitna River from the west, the junction of the two rivers being about 25 miles above the mouth of the Susitna. The area embraced in the Yentna district, as that term is commonly used, lies along the southeast base of the Alaska Range and includes all the drainage basin of Yentna River above the mouth of the Kahiltna, except the basin of the Skwentna, a large tributary from the southwest. The position of the district and its relations to Susitna River and Cook Inlet are shown in Plate I. The accompanying map (Pl. II, in pocket) shows what is known of the geography between meridians 150° and 152° west longitude and parallels 61° and 63° north latitude, but the descriptions in the following pages are confined to a triangular area of about 2,050 square miles (Pl. I), shown in the center of the map and bounded roughly by Yentna River on the southwest, the Susitna lowland on the east, and the rugged portion of the Alaska Range on the northwest.

PREVIOUS WORK.

Before the work was done on which this report is based little was known of the geology of the region between Yentna and Susitna rivers beyond a few facts of a general nature which had been gained from various sources. No attempt had been made to map the geology or to learn the relations between the various formations. In 1898 Spurr[1] ascended the Yentna to the mouth of the Skwentna and traveled up the valley of that stream, but in his journey along the Yentna he was able to obtain little information about the geology of the country to the north. During the same year Eldridge[2] made

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 31–264.

[2] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: Idem, pp. 1–30.

an exploratory trip up the Susitna and into the Tanana basin and recorded many facts about the geology of the range in the northern part of the Susitna basin. In 1902 Brooks and Prindle, in their exploration of the north side of the Alaska Range, went up Kichatna River and secured a geologic section of the range along their route. The results of all these early investigations have been embodied in a recently published report.[1]

The conditions under which these explorations were carried on, however, rendered it impossible for the geologic work to be extended more than a few miles on either side of the route of travel, and as both Yentna and Susitna rivers lie in broad, alluvium-filled basins, in which there are few bedrock exposures along the streams, the geologic conditions in the upland area between them were unknown, except for a few facts gleaned from reports of prospectors and miners who had visited the region.

In 1906 a reconnaissance topographic map, covering approximately the area considered in this report was made by R. W. Porter under private auspices. This map has already been published [2] and with a number of additions and corrections by the writer is again published here (Pl. II, in pocket), and is used also as the base for the geologic map (Pl. III, in pocket).

Gold was first discovered in the Yentna district in 1905 by a party of men who started up the Susitna by boat, intending to go to Valdez Creek, a headwater tributary of the Susitna from the northeast. Above the main forks of the river they encountered such difficulties that they changed their plans and ascended the Chulitna and Tokichitna to Home Lake, where they established a base camp from which they made prospecting trips that resulted in the discovery of gold in the Peters and Cache Creek basins.

Since 1905 prospecting and mining have been carried on continuously, and although gold has been found to have a widespread distribution throughout the area, it has been obtained in paying quantities only in the so-called Cache Creek country, in the basin of Twin Creek, and at a few points in the valleys of Lake Creek and Kahiltna River. During the season of 1911 a new impetus to prospecting was given by the discovery of rich placer ground in the benches above Dollar Creek. At present the whole economic value of the district is in its placer gold, no valuable lodes being known. Lignitic coal occurs at many places, but its quality is too poor to attract much attention, as better and thicker coal beds occur at easily accessible points on Cook Inlet. The coal has, however, some value as fuel for local use.

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911.
[2] Idem, Pl. XV.

PRESENT INVESTIGATION.

As developments over a period of several years showed that the placer gold production from the Yentna district was steady, and the mining population was gradually increasing, it became desirable to learn more accurately the conditions under which the gold occurs, to discover if possible the source from which it was derived, and to ascertain as far as possible the extensions of the area in which paying concentrations of gold were likely to occur, as well as to map areally the distribution of the rock formations, and to learn their relation to one another. For this investigation the writer was detailed, accompanied by J. M. Charles, packer and cook. McDougall, at the mouth of Lake Creek, was reached on June 9, 1911, by launch up Susitna and Yentna rivers. At this point three horses were procured as pack animals, and the party proceeded directly to the placer-mining district on Cache Creek, where actual field work began on June 26 and was continued until September 13, a period of 80 days, during which an area of 2,050 square miles was mapped. It will thus be seen that time was available only for a hasty investigation of the conditions at the various placer mines, and for determining the more important facts about the surface distribution of the different rock formations. The boundaries given on the map (Pl. III, in pocket) can therefore be regarded as accurate only in so far as they show the general distribution of the formations. The smaller but none the less important details of structure, distribution, and relation of the various formations remain for a later, more detailed investigation, which will doubtless be made if developments in the region justify it. A preliminary report on the mineral resources of the Yentna region has already been published.[1]

The writer wishes to express his sincere thanks to the miners and prospectors of the region for their hearty cooperation and unfailing hospitality, especially to Mr. C. P. Morgan, who made a considerable sacrifice of time to aid in the work and supply information, and to Mr. B. M. Mathieson, who furnished a traverse of Cache Creek and parts of its more important tributaries.

GEOGRAPHY.

DRAINAGE.

SUSITNA RIVER.

The Susitna is the master stream that receives all the southward drainage of the Alaska Range for nearly 300 miles, measured along the crest of the range. From the west it is fed, in the region under discussion, by Chulitna River and its tributary the Tokichitna, by Deshka

[1] Capps, S. R., Gold placers of the Yentna district: Bull. U. S. Geol. Survey No. 520, 1912, pp. 174-200.

River, and by the Yentna. The Tokichitna is a short stream—little more than 25 miles in length—which receives the drainage from one small and two very large glaciers. In the mountainous upper portion of its course it occupies a broad glacial trough, which extends eastward to the east base of Peters Hills, beyond which the valley walls become lower, and the stream enters the lowlands of the wide Susitna basin. Below the small glacier in which the river heads it has the character of most glacial streams, being heavily charged with gravel and silt and spreading in a multitude of channels across a wide valley floor. The channels shift constantly, the stream cutting away the banks at one place to redeposit the materials at another. Of the Deshka little is known except that it receives no water from the mountains and that its course lies wholly in the Susitna lowland, roughly parallel to that of the Susitna. It joins the Susitna about 10 miles above the mouth of the Yentna.

YENTNA RIVER.

Yentna River is the largest tributary of the Susitna. It rises in the rugged mountains of the Alaska Range near Mounts Russell and Dall and flows southeastward to its junction with the Susitna, about 25 miles from the coast. It receives much of its waters from the glaciers and snow fields of the higher portions of the range, but as the mountain mass at the head of the main forks of the Yentna is lower than that portion which lies farther north, the glaciers there are smaller and the valley is free from ice much farther into the mountains than are the neighboring valleys to the north. Above the junction of the two main branches which form the river both streams have the characteristics of other glacial streams, with many branching channels and wide expanses of bare gravel and sand bars. Below the junction of the headward forks the river maintains a more definite channel, with few islands, and is easily navigable by light-draft launches. The principal tributary of the Yentna from the north is Kahiltna River, which heads in the great Kahiltna Glacier. This glacier lies in a basin which is difficult of access and much of which is still unexplored. It is believed, however, that the glacier receives ice from the slopes of Mount Foraker, and it is possible that it drains some of the snow fields on the southern slope of Mount McKinley. The glacier sends its terminus out beyond the confines of the higher mountains and at its lower end is nearly 4 miles wide. Below it Kahiltna River is turbid and spreads with many channels and sloughs across a broad flat which lies at an elevation less than 600 feet above sea level. This flat narrows noticeably about 15 miles below the glacial source of the stream, and for much of the remainder of its course to the Yentna the river flows as a single stream through a narrow canyon-like valley. Be-

tween the glacier and the Yentna the river receives water from several large creeks whose basins lie below the level of perpetual snow. Lake Creek, which joins the Yentna 8 miles above the Kahiltna, heads in high mountains between Kahiltna and Yentna glaciers, and although its basin contains no large glacier many of its headward tributaries are fed by small ice fields. A number of these drain into Chelantna Lake, a body of water 7½ miles long and 1 mile wide, which occupies the lower end of the mountain valley and which at its lower end gives rise to Lake Creek. Above the lake the glacier-fed streams are muddy with glacial silt, but below it Lake Creek is clear and flows, with a sluggish current, to the southeast as far as Willow Mountain in a shallow valley, across the surface of the upland plateau. East of Yenlo Hills the stream has entrenched itself and lies in a gorge which at the mouth of Yenlo Creek is 250 to 300 feet deep. Through this gorge the creek is swift and runs in a series of rapids over large bowlders. Near the mouth of Lake Creek the valley widens, and the stream gradient becomes more gentle. The most important tributaries of the Yentna from the south are Skwentna and Kichatna rivers, but they lie outside the area with which this report is concerned.

Yentna, Kahiltna, and Tokichitna rivers all have their sources in large glaciers, and their upper portions have many characteristics in common, due to their mode of origin. During spring and summer the glaciers melt rapidly, and large volumes of water are discharged, the floods usually reaching their culmination late in June or early in July. The waters on emerging from beneath the ice are heavily charged with gravel, sand, and silt, and to this load is added whatever material the streams are able to pick up from the moraines and gravels of the upper valleys. This heavy load of débris can be carried by the streams only where their gradients are steep, and as the valley slopes diminish downstream the materials are deposited, the coarse materials being dropped first and the finer farther downstream. Such rapid deposition causes the streams to shift their channels frequently, and for many miles below the glaciers the streams are characterized by a network of branching channels, and bare gravel and sand bars. This deposition causes the gradual upbuilding of the valley floors with heavy beds of stream-laid deposits, and the widening of the valley floors over which the streams spread. An excellent example of this process is to be seen immediately below Kahiltna Glacier, at which place a flat almost treeless expanse of bare gravel and sand stretches across the valley for a distance of nearly 4 miles. Glacial streams are especially subject to rapid fluctuations of volume during the summer, and warm clear days or warm rains always cause the glaciers to melt rapidly and the streams to swell. On the other hand, a cold, crisp night will cause the streams to shrink, and the early morning after such a cold night is preferred for fording the rivers by those

acquainted with the conditions. In the late fall and in winter, when glacial melting is at a minimum, the rivers are low and the waters are clear.

RELIEF.

LOWLANDS.

The Yentna district, bounded by Susitna and Yentna rivers and the crest of the Alaska Range, may be roughly divided into three distinct topographic provinces—the lowlands, the foothill belt, and the Alaska Range. Of these the first includes the lowlands of Yentna, Susitna, and Tokichitna rivers (Plate III, in pocket). It stretches west from the base of the Talkeetna Mountains on the east side of the Susitna to the foothills of the Yentna district, a distance of nearly 50 miles, and has irregular projections which extend up the valleys of Yentna, Kahiltna, and Tokichitna rivers. Most of the lowlands lie within 600 feet of sea level. They are characterized by broad, almost flat stretches along the main streams and by slightly rolling interstream areas. The lowlands are nearly everywhere covered with spruce or cottonwood timber, and between the trees willow, alder, and other bushy plants grow in profusion. The larger streams which cross the lowlands have well-defined valleys and most of them flow with a swift current and are turbid. The smaller streams, on the other hand, are clear and commonly sluggish and meandering; they flow in poorly defined channels that drain the many marshes and small lakes with which the lowland is dotted. As the lowland is marshy and difficult to penetrate on account of the heavy growth of brush, it has been little explored, for it offers no attraction for either the prospector or the geologist.

FOOTHILLS.

The second topographic province includes the foothill belt that lies between the lowland and the rugged mountains to the northwest. In this belt are the Dutch, Peters, and Yenlo hills and the hills at the head of Twin and Camp creeks. In general, all of these hills are smooth in outline (Pl. IV, *A*), and their summits reach elevations of 3,000 to 4,000 feet, although at the north end of the Dutch Hills somewhat rougher peaks rise to a height of 5,000 feet. Between the hill ranges and around their margins is a high upland plain cut transversely by the Kahiltna Valley and sharply trenched by many of the streams which cross it, but which still retains enough of its old surface to be recognizable. Between Yentna and Kahiltna rivers this plain lies at an elevation between 800 and 1,600 feet, and at its upper edge gives place to the rugged mountains of the Alaska Range (Pl. IV, *B*); in the basin of Cache Creek it rises to a height of about

A. PETERS HILLS, WITH CACHE CREEK TROUGH IN FOREGROUND.

B. CHELATNA LAKE AND THE ALASKA RANGE, LOOKING NORTHEAST.

Mounts McKinley and Foraker in the distance, at the left. The lake lies in a glacially scoured valley behind a moraine dam, its lower end marking the boundary between the alpine belt and the uplands that surround the foothills.

MOUNT McKINLEY FROM THE SOUTHEAST.

(Photograph by La Voy.)

2,000 feet and is bordered by the foothill ranges. Very little of this high plain is heavily timbered. Scattered groves of spruce occur in favorable localities, but most of the vegetation consists of low bushes, grasses, and sphagnum mosses. All the producing placer mines are within this belt.

MOUNTAINS.

The third region, of very different character from the others, comprises the rugged alpine portion of the Alaska Range. The dividing line between it and the foothill belt extends from the lower end of Tokichitna Glacier southwest to Yentna River at a point a few miles above its forks. The mountains in the lower southeast portion of the alpine belt have elevations of about 4,000 feet, but to the northwest the range increases rapidly in height and ruggedness, culminating in the two great mountains which on clear days may be seen to dominate the whole Susitna basin—Mount Foraker, 17,000 feet, and Mount McKinley, 20,300 feet in elevation, the loftiest peak of the continent (Pl. V). Between the foothills and the crest of the range is a belt averaging about 25 miles in width and including an area of many thousand square miles of unexplored territory that is most difficult of access on account of the sharp, toothlike character of the ridges and the glacier-filled valleys. The Alaska Range, considered as a whole, forms a great crescentic curve, its trend being in a north-south direction west of Cook Inlet and in an east-west direction between the Copper River basin and Tanana River. The Yentna drains an intermediate portion of the range, in that part where its trend is from southwest to northeast. Here, for a distance of 150 miles measured along the crest, the massive mountains are unbroken by passes, and the only practicable routes from Susitna basin to the interior are across the range at one of the three neighboring passes at the heads of Kichatna and Skwentna rivers into the Kuskokwim basin, or across one of the passes at the head of the Chulitna or the Susitna into the Tanana basin.

Both the topographic and geologic mapping of the high, mountainous area of the Yentna district have been limited to its more accessible portions, along the flanks of the range. The topographic map thus gives undue emphasis to the rounded and smoothed forms of the foothill ranges and presents an inadequate idea of the extreme roughness and scenic grandeur of the heart of the range. The location and elevation of only a few of the most conspicuous mountains are given, although hundreds of unnamed and unrecorded peaks from 8,000 to 14,000 feet in height are distributed throughout the unmapped area between the front of the range and its crest. If the map were complete, it would show that these peaks occur along narrow, steep-sided ridges, the space between them being occupied by

great glaciers and their branching tributaries (Pl. VI, *A*). The erosive action of the extensive ice bodies which still remain and of the much greater glaciers of which these are the shrunken remnants has been of prime importance in shaping the mountains to their present forms. By the removal of spurs and irregularities along their sides the glaciers have reduced the valleys in which they lay to deep straight-sided troughs, which, where they bend, swing in broad, sweeping curves. In both the tributary and the main valleys the same development of broadly U-shaped, straight valleys has taken place. In the small valleys the headward growth of opposing cirques has reduced the divides to serrate, pinnacled ridges.

INFLUENCE OF ROCK TYPES ON TOPOGRAPHY.

Although the tendency of glacial erosion is to reduce all the divides to sharp ridges, the character of the rocks of which the mountains are composed has exercised an important influence on the mountain forms. In the higher parts of the range the most widespread rocks are of granitic character, and from these are produced acute, almost needle-like summits and pinnacles. The slates along the flanks of the range also take on rugged forms but in a lesser degree than the granitic rocks. Most of the foothill ranges are composed of slates and graywackes, but these were probably at one time completely overridden by glacial ice, and their summits smoothed off and rounded, to be later dissected by the erosion of many small valley glaciers along their sides. Cirques were developed by these valley glaciers, but their growth was not sufficient to obliterate the smooth outlines of the hills or to notch the crest lines in any conspicuous way. The gravel hills between upper Lake Creek and Yentna River have their own distinctive topographic form, although the erosive effects of the glacier which once overrode them are still visible. These hills are smooth in outline, but sharply incised gulches mark the slopes which have been most subjected to postglacial stream erosion. In the plateau region surrounding the foothills, and in the lowland toward the east, the larger topographic features are due to the form of the underlying deposits left by the ice, but the smaller details of surface configuration are due to the manner in which the surface materials were laid down, being of a mild hummock and kettle topography where morainal deposits occur and flat and featureless in those places where stream deposits are present.

CLIMATE.

The placer camps of the Yentna district, though only about 80 miles from tidewater at the head of Cook Inlet, are more than 200 miles from the main line of the Pacific coast and have a climate more like that of interior Alaska than of the coastal region. No systematic

records of temperature or precipitation are available for the Susitna basin, but it is known that the winters are colder and the summers warmer than along the coast, where the ocean currents have an equalizing effect on the temperature. The snowfall in winter is less than on the coast, but is heavier than in the Yukon basin in the interior. The region is surrounded by high mountains on all sides except where Cook Inlet makes a narrow opening, and these mountains greatly influence the distribution of the precipitation. The number of rainy days and the amount of rainfall during the summer seems to vary greatly in different seasons. R. W. Porter notes that in 1906 it rained 50 days of the 110 he spent in the field. The summer of 1911 is admitted by the miners to have been unusually dry, but during 100 days spent in the area above Cook Inlet it rained steadily on 16 days and for parts of 9 other days.

The seasons consist of a long winter of about seven months, from October to April, during which the streams are frozen; a period of a month or so in the spring, the so-called "break-up," during which the streams become free from ice, and most of the snow melts in the lowlands; a short summer of about three and one-half months, during which the days are long and warm and vegetation grows with remarkable luxuriance; and a fall of a few weeks, when the days are clear and crisp and the nights cold, which lasts until the rivers freeze up for the winter. In the fall the streams become low, and slush ice usually forms between the 20th of September and the middle of October, closing navigation on the rivers until about the middle of the next May. The rivers, however, become free from ice in the spring long before the snow disappears from their banks. The spring of 1911 was said to be unusually late, but at the mouth of Lake Creek, only 200 feet above sea level, snow still lay in the timber, in sheltered places, on the 10th of June and on the Cache Creek Plateau, at an elevation of 2,000 feet, there were large patches of snow in early July. The discharge of the streams is very low in midwinter but increases with the melting of the snow and even after the snows from the lowlands have largely disappeared. The higher portions of the Alaska Range are occupied by perpetual snow fields and by great glaciers, and the periods of greatest floods for the glacier-fed streams come in the middle of July, when the days are warmest and melting is most rapid in the glacial fields. As fall approaches and the nights become longer and colder this melting decreases, and the streams in consequence shrink; for a short time before the freeze-up glacial activity becomes so reduced that little water is discharged, and the streams become clear, in contrast to their turbid state in times of high water.

In those streams that do not receive water from melting glaciers the high-water period comes earlier, in June, when the melting of the

winter snows is greatest. Heavy rains during the summer cause floods in these streams, but the general tendency is toward a gradual diminution of flow after the first of July, and when the snows have disappeared from their basins many of the smaller creeks dwindle or go dry completely, unless the run-off is augmented by rains.

VEGETATION.

As the snow melts away in the spring and the days become long the growth of vegetation is astonishingly rapid. Scarcely has the ground become bare of snow before the plants spring up, and a line of green follows the edges of each diminishing snow patch, separated from it by only a few feet of bare ground. From that time until frost in the fall the growth is of almost tropical luxuriance. Grass of a variety known as "red top" appears soon after the snow has gone, and affords good forage for horses until withered by frosts in the fall, after which it yields little nourishment to stock. It is abundant throughout the Yentna district, from the lowlands of Susitna River up to elevations of 3,000 feet on the mountain sides, and grows to a height of 4 or 5 feet. Many areas hundreds of acres in extent were seen in which this grass grew densely. It makes good hay when cut before frost and properly cured. Between the 1st and 10th of June grass sufficient to supply forage for horses appears at McDougall, but in the higher basins, such as that at the head of Cache Creek, the snow does not always disappear until early July, and horse feed is not abundant until that time. Horses also feed freely on plants of the genus Equisetum, locally known as horsetail rushes, and on various other plants, but the forage fails in late September, and horses can not be worked after that time unless fed on hay and grain.

The distribution of timber in the region is shown in figure 1. Throughout the lowlands of the larger river valleys there is an abundant growth of spruce and cottonwood timber, with some birch on the well-drained hillsides. Timber is found in the main valleys of the mountains and up to an elevation of about 2,000 feet, although there is much untimbered territory below this level. The largest trees grow on the lower ground; there the spruce reaches a maximum diameter of about 24 inches, and cottonwood trees 5 feet through at the base were seen. Near timber line the trees are generally small and scrubby and unfit for lumber. Above timber line there is in most places a belt of dense alder or willow brush, which is difficult to penetrate and which necessitates much chopping for the passage of horses. Alders and willows also grow thickly in the lowlands among the timber and here attain large size, making it a laborious task to chop a trail through them. Even in those places where a trail has been cut out, continuous travel and chopping are

required to keep it open, for the winter snows press down the brush from either side, and new branches spring out to fill the openings, so that in a few years a trail, if left to itself, will be obliterated. Sphagnum mosses grow profusely both in the timber and brush and

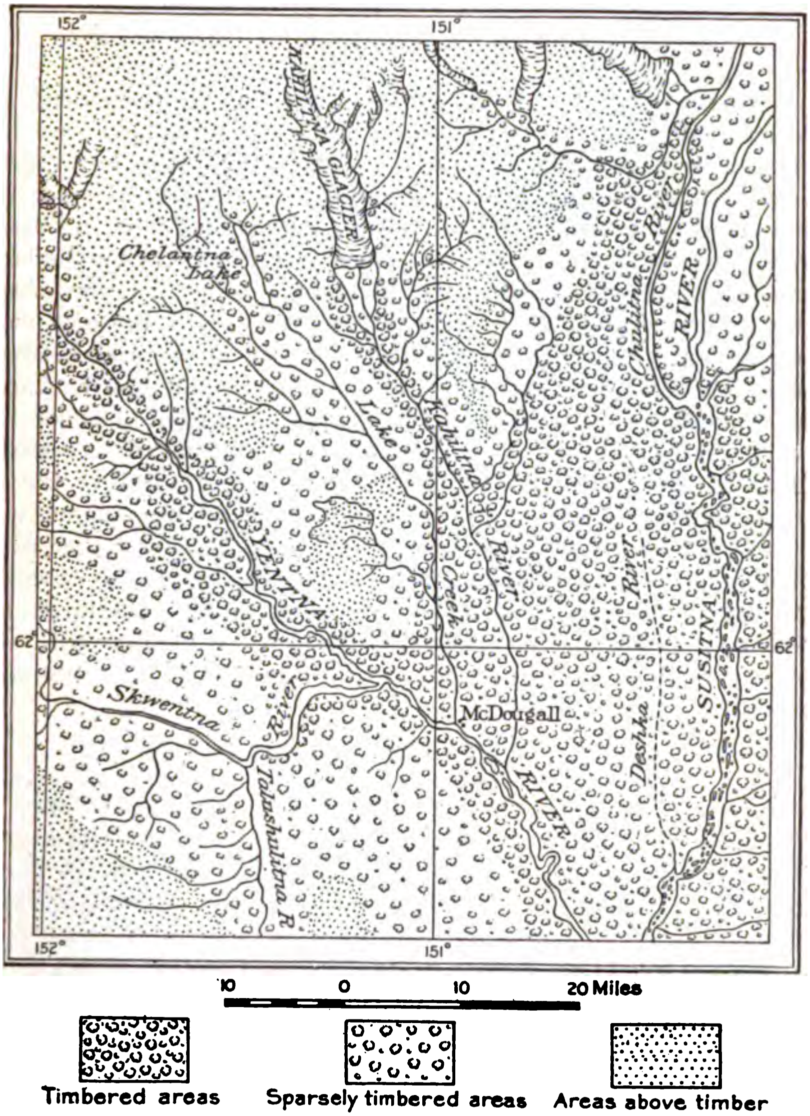


FIGURE 1.—Sketch map showing the distribution of timber in the Yentna district.

above timber line. They absorb and hold large quantities of water and by their protective covering keep the ground frozen in the spring long after the bare ground has thawed out. Above timber line the

moss-covered surface was in many places observed to consist of dome-shaped hummocks (Pl. VII, *B*), the origin of which is not clear.

Some edible berries grow within the region, the most important of which are blueberries and cranberries above timber line and some raspberries, currants, and high-bush cranberries in the timbered areas.

POPULATION.

Until the discovery of gold in 1905 there were no permanent settlements of white men in the whole Yentna district, and very few white men had visited it at all. In 1905 there were less than a dozen men prospecting on the various creeks, and in 1906 it is reported that about 50 men were prospecting and mining on Peters and Cache creeks and their tributaries, an unrecorded number being similarly engaged on the headwaters of Lake Creek. No records have been kept for the years 1907 to 1910, but in 1911 about 100 men were working on Cache and Peters creeks, 10 men in the area between Lake Creek and the Yentna, and perhaps half a dozen on Kichatna and Nakochna rivers, south of the Yentna, or a total of about 116 within the Yentna district. There are no permanent native settlements in the Yentna basin, the nearest being at Susitna and at Alexander, on Susitna River. The Indians spend the summer and most of the winter on the main river, where they have rather comfortable log cabins. The summers are largely occupied in catching and drying fish, an occasional hunting trip being undertaken for fresh meat. The natives along the Susitna are familiar with the country drained by the Yentna, and make hunting and trapping expeditions into it in the fall and winter.

SUPPLIES AND TRANSPORTATION.

The only practicable route to the Yentna district is by way of Susitna and Yentna rivers. During the summer months the Alaska Northern Railroad may be used from Seward to the head of Turnagain Arm. From the terminus of the railroad, as well as from Seldovia and other points on Cook Inlet, launches carry both passengers and freight up Susitna River to Susitna Station, which is the center of supplies for the Yentna country. Launches make occasional trips during the summer from Susitna Station up the Yentna, which is navigable for light-draft boats almost all the way to the forks of the river. A trading station was formerly maintained on the Susitna near the mouths of Talkeetna and Chulitna rivers, and a stern-wheel steamboat plied up the river to that point. This station has now been abandoned, and the steamboat taken to another part of Alaska. The route most followed to the placer camps in the neighborhood of Cache Creek leaves the Yentna at McDougall, a small village at the mouth of Lake Creek. From McDougall a wagon road

A. PASS BETWEEN BEAR AND PETERS CREEKS AND A GORGE IN THE SLATE AND GRAYWACKE SERIES OF DUTCH HILLS.

B. MOSS HUMMOCKS ON UPPER PART OF DUTCH CREEK.

has been built, which follows the east bank of Lake Creek upstream for about 15 miles and then swings across to Kahiltna River. A bridge which was built across the Kahiltna was washed out in the spring of 1911, so that it was necessary to swim horses at this point, passengers crossing in rowboats. Beyond the Kahiltna the trail follows the high ground along the west slope of Peters Hills and across several miles of marshy ground, which in summer may be crossed by horses with difficulty. Cache Creek valley is reached at the mouth of Spruce Creek and followed upward from that point. As supplies can be transported overland much more cheaply by sled in winter than by any means in summer, and as the winter is the season during which the miners have most leisure, open-cut mining methods being impossible until the streams run free of ice in the spring, almost all of the freighting is done in winter, either from Susitna Station or from McDougall. From the former point the sled route follows Susitna and Yentna rivers either to the mouth of Kahiltna River or to McDougall, depending on the part of the country to be reached. Much of the freight for Peters Creek and its tributaries has been taken up Kahiltna River and Peters Creek. Practically all of the freighting for Cache Creek is done by way of McDougall and the wagon road to the Kahiltna. From the trail crossing at Kahiltna River the winter route most used ascends Kahiltna Valley for some miles and then swings up the slope to meet the summer trail a few miles south of Cache Creek. Until 1907 this region was supplied in summer by a pack train, which used a trail from a point on Yentna River near the forks and, following a course parallel with the base of the mountains, crossed the Kahiltna just below the glacier. It then lay along the northwest edge of the Cache Creek basin and terminated at Home Lake, in the Tokichitna Valley. This trail is now little used, and though portions of it can still be distinguished it is for most of its length so overgrown by brush and grass that one not familiar with its course would have difficulty in following it.

The diggings in the basin of Twin Creek are most often reached by following the Yentna to McDougall, from which supplies are sledded up the wagon road to a point more than half way to the Kahiltna. Here a winter trail branches to the westward and follows up Lake and Camp creeks. In leaving the country in the fall the miners from Twin Creek usually build boats or rafts and float down the Yentna. From Cache Creek the trail and road are used to McDougall and launches are taken from that point to Susitna Station. From the headwaters of Peters Creek the trail to Tokichitna River is often followed, and boats are built to descend this stream and the Chulitna to Susitna River.

One of the serious problems which confront the miners in the various camps is the difficulty of obtaining timber suitable for sawing into lumber for sluice boxes and for other mining uses, as most of the mines are located above timber line. Cache Creek valley and its branches formerly contained some spruce timber up to the point where a sawmill was built, a mile or more above the mouth of Thunder Creek. The heavy demand for logs for the sawmill has caused the cutting away of all the best trees as far downstream as the mouth of Spruce Creek, so that a haul of at least 7 miles to the sawmill is now necessary. A toll of half the logs brought in is charged the miners for sawing at this mill. Peters Creek is timbered below the lower canyon, and logs for lumber and fuel are brought from that locality to the diggings on upper Peters Creek and its affluents. Some logs are also procured for these camps from the Tokichitna Valley. Lumber and fuel for the mines on Mills and Twin creeks are obtained from the lower reaches of these streams, a few miles below the camps.

GEOLOGY.

PRINCIPAL FEATURES.

The distribution of the geologic formations represented in the region is given on the accompanying map (Pl. III, in pocket), and the relations of the various formations to one another are shown in figure 2. The oldest rocks of the district consist of a series of slates and graywackes, which form the cores of all the foothill ranges and are an important element of the Alaska Range, especially along its southeastern flank. The slates and graywackes are interbedded, in some places in about equal amounts, in other places one or the other phase predominates. The slates vary in character from place to place, ranging from fissile, thin-cleaving rocks to more massive argillites, and the high development of the lines of schistosity in many localities makes it difficult to determine the original bedding of the sediments. The graywacke is generally hard and massive and in some of its phases is with difficulty distinguished from fine-grained dike rocks, for which it is often mistaken by the miners. This slate and graywacke series forms the hard bedrock of the placer camps in the Cache Creek basin.

After the sediments of which the slates and graywackes are composed were deposited they were metamorphosed almost to their present state, the changes consisting of an alteration from muds and sands into hard slates and graywackes. This was accompanied or followed by rather intense folding and faulting, which probably took place while the materials were buried beneath a heavy covering of later sediments. The metamorphosed series was then intruded by large masses of granitic rocks, which formed great laccoliths in the slates and which

sent out many dikes into the surrounding rocks and still further metamorphosed the materials near the contacts. The whole mass was then uplifted, and erosion exposed the intrusive masses which now form much of the high part of the Alaska Range. The effects of the intrusion are seen in the abundant veins of quartz which are found in the slates for several miles from the borders of the

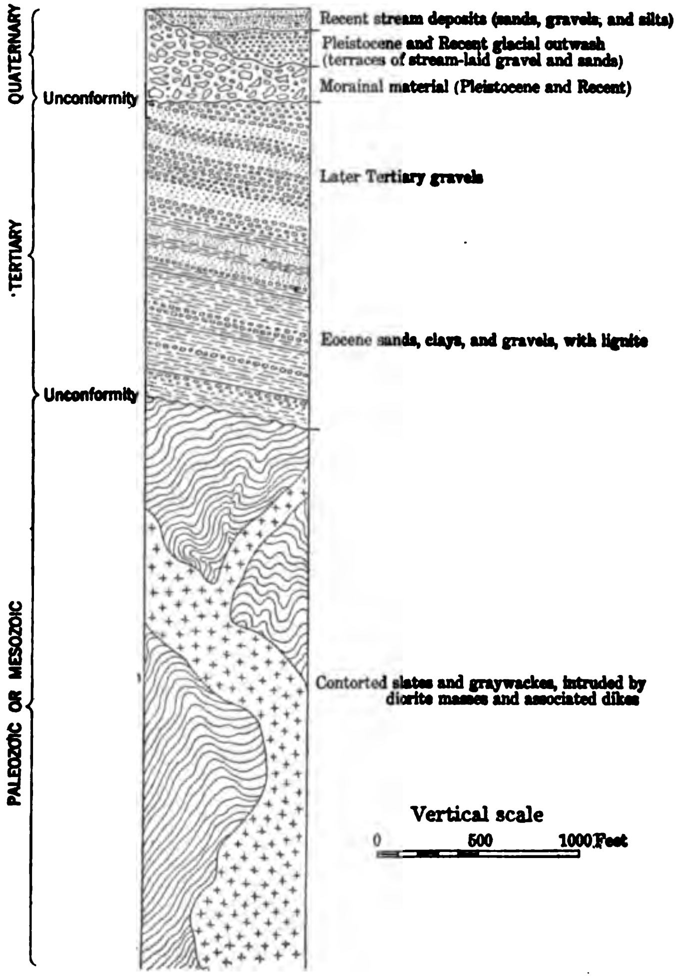


FIGURE 2.—Generalized columnar section of the rocks of the Yentna district.

intrusives, and it is probable that these veins are the source from which the placer gold of the district has been derived. The evidence at hand regarding the age of the slates and of the granitic rocks will be discussed in a later paragraph.

Tertiary beds, composed of little-consolidated sands, shales, gravels, and some lignitic coal, overlie the slates in the more favorably

situated depressions between the foothill ranges and extend eastward from these hills, the beds forming the so-called "soft bedrock" of the miners. They disappear beneath the later deposits of the Susitna basin, but their structure along the slopes of the Yenlo and Peters hills, and their presence in the deep canyons of Kahiltna River and Lake Creek indicate that they probably underlie much of the broad Susitna basin. Coal that probably formed a part of these beds has been mined on the south bank of Yentna River, about 7 miles above its mouth. In the area near the head of Twin and Camp creeks the coal-bearing series is overlain by a heavy deposit of stream-washed gravel, much coarser than anything seen in the coal-bearing series itself. Exposures of this gravel series are also found on the west side of Treasure Creek. The gravels are many hundred feet thick and seem to be structurally conformable on the coal-bearing beds.

Next younger than the Tertiary sediments and the associated gravels is the widespread blanket of glacial materials that masks the older formations throughout a great part of the area outside of the high mountains. The glacial beds consist of morainic materials deposited directly by glacial ice and of gravels which were laid down by the glacial streams. The morainic material in most places consists of tough blue clay, in which gravels, bowlders, and angular pieces of rock are embedded and in which there is a complete lack of assortment of materials such as is found in water-laid beds. Glacial striations are particularly abundant on the rocks in the glacial till in this region. The glacial gravels form most of the benches along the sides of the stream valleys. The glacial deposits shown on the map (Pl. III) vary greatly in thickness from place to place, but over the area shown they are of sufficient thickness to conceal the underlying formations. The latest deposits considered are the gravels of the present streams, which form narrow strips along most of the creek valleys and cover large areas in the basins of the more important rivers.

SEDIMENTARY ROCKS.

SLATE AND GRAYWACKE SERIES (PALEOZOIC OR MESOZOIC).

Distribution and character.—A thick series of slates and graywackes forms the underlying hard bedrock throughout a large part of the area here considered. Its surface outcrops (Pl. III, in pocket) extend from Yenlo Hills to a point far up the Yentna, probably to the glaciers on the East Fork and from the Yentna in a northeast direction beyond Tokichitna River. As will be shown later, what are probably the extensions of this series stretch both north and south of the Yentna region. Within the limits defined, however, the slates and graywackes form an important part of the alpine portion of the Alaska Range, especially along its flank, and form the

cores of both Dutch and Peters hills (Pl. VII, *A*). They consist chiefly of black to gray slates and phyllites, in many places carbonaceous, and beds of graywacke, which range from fine-grained to coarse gritty rocks. In some places the rocks are massive, with argillites instead of slates, but the foliated types are much more widespread than the massive types. It is difficult to estimate just what proportion of the whole series is formed by the graywacke beds. Many sections show great thicknesses of the slaty phases, with very little graywacke present. At other localities the graywackes preponderate, occurring in thick, massive beds that show little foliation or schistosity and that are often mistaken by the miners for fine-grained dike rocks, which they closely resemble. The whole series is much jointed, the graywackes less closely than the slates, which are in many places broken into long prismatic pieces by sets of intersecting joints. In the Yenlo Hills, in addition to the usual slates, phyllites, and graywackes, there are certain siliceous beds of the series that are almost quartzites and that are intricately and closely cut by tiny veinlets of quartz. Evidences of mineralization are widespread in these rocks. A characteristic phase of the slates in many places throughout the region contains small cubical cavities, the largest a quarter of an inch in diameter, formed by the leaching out of cubes of iron pyrite, the rock being discolored for some distance around each cavity. Some of the graywacke beds also show the presence of much finely disseminated pyrite.

Glaciation in the slate area has been so severe and the mechanical weathering of the high mountains in postglacial time has been so rapid that few opportunities are afforded for the study in place of the residual materials formed from these rocks. At several places, however, where the slate series was overlain by Tertiary deposits, the old pre-Tertiary weathered surface has been preserved, to be exposed by recent stream cutting. At these localities the slates, when deeply decayed, break down into whitish and bluish kaolinic clays, and the graywacke beds, by the removal of the cementing material, yield soft arkosic sandstones.

In the higher mountains a great mass of granitic rocks has been intruded into the slates, and for several miles from its borders dikes of various kinds of rock occur. Most of the dikes are narrow and of no great length, and no attempt has been made to map any but the larger masses. Nevertheless, the intrusions as a whole have had an important influence on the economic development of the district. The intrusive rocks will be described in another section of this report. Along the contact with the great intrusive mass of the main range the slates and graywackes have been profoundly metamorphosed into hard dense rocks, which under the microscope show,

besides carbonaceous material and quartz, such secondary minerals as biotite, muscovite, garnet, andalusite, and cordierite. The extreme effects of contact metamorphism appear for only a short distance beyond the contacts, but an unusual amount of mineralization is present for several miles from the intruded bodies. The abundance of quartz veins is also dependent on nearness to the contact, the number and size of the veins being greatest near it, and decreasing with distance. Few veins which might be called true fissure veins were seen, most of them being small gash veins of irregular shape or even minute leaf-like stringers. In the rocks of the slate series, within 8 or 10 miles of the intrusive contact, all of the gold-producing streams of the Cache and Peters creeks region have their heads, and the mineralization of the slates is in large measure due to the influence of the granitic intrusions and of the associated dikes. Though as yet no gold has been found in veins in place, pieces of small quartz veins with adhering slate walls, containing free gold, have been found in the sluice boxes on several creeks, and this and other known facts point to the veins in the slate and graywacke series as the source of the gold which is now being recovered by placer methods from the streams in the Cache Creek region.[1]

Structure and thickness.—Structurally the slates and graywackes are everywhere folded and faulted, though in varying degree in different places. In some localities the folds are gentle, and for some distance the beds appear to have uniform dips and seem to be merely tilted. Other exposures show intense folding in more than one direction, a wide range of strikes and dips being seen within short distances. Even hand specimens of the rock may show complex systems of minute folds. The development of a slaty cleavage and of well-defined systems of joints adds to the difficulties of working out the structure of the series, as either the direction of cleavage or of a pronounced system of joints may be mistaken for the planes of bedding. The most reliable readings of the true strike and dip in any locality were found to be those taken on beds of graywacke interbedded with the slates, for these denser beds are less readily metamorphosed than the slates and seldom show foliation or schistosity. A large number of strike and dip readings show that the trend of the strike is almost everywhere in a general northeast-southwest direction, the average being N. 62° E., parallel with the trend of the Alaska Range. There is greater variance in the direction and angle of dip of these rocks, as is to be expected from the presence of minor folds, but the majority of the dips were to the southeast, away from the high mountains, the average dip being about 60° in that direction.

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[1] A quartz vein containing visible free gold is said to have been found on upper Nugget Creek since this report was written. This discovery strengthens the conclusion already reached—that the quartz veins in the slates and graywackes are the source of the gold found in the stream placers.

It will thus be seen that the slate and graywacke series lies on the limb of a great structural anticline which parallels the axis of the mountain range. In the southward continuation of this series Brooks[1] has found similar conditions to prevail in the Kichatna basin. In addition to the folding the rocks have also been severely affected by faulting. One fault is known in which the displacement must be measured in thousands of feet, and doubtless there are many other faults which escaped detection, as the character of the beds is so uniform throughout the series that offsets are inconspicuous, and the surface scarps have as a rule been removed by glacial erosion. The facts known are not sufficient to justify estimates of the thickness of the series. The dips may be fairly uniform through considerable distances, but the problem is complicated by the possibilities of unknown faults which may reduplicate the beds. It is certain, however, that the series is several thousand feet thick. Brooks[1] gives a provisional estimate of 2,000 to 3,000 feet for the section along the Kichatna Valley, and this seems a very moderate estimate for the Yentna region.

Age and correlation.—Within the area studied the formations which underlie the slates and graywackes were nowhere seen and nothing was learned about them. The metamorphism and erosion which the slates and graywackes have suffered indicate that a long period intervened between the deposition of these rocks and those next younger, the Tertiary coal-bearing beds. A careful search for fossils in many places failed to reveal anything which might aid in the determination of their age. Nothing was learned, therefore, to establish their age beyond the fact that they are pre-Tertiary. On the continuation of this belt in the Kichatna Valley, Brooks[2] has made the following statement:

The slates above described are overlain by rocks assigned to the Middle Jurassic. They resemble somewhat the argillites on the west side of the Alaska Range which form a part of the Tonzona group and are assigned to the Silurian or Devonian. They are also somewhat similar to the metamorphic sediments of the Knik Arm region, which have been described on page 61. The structure of the cross section of the Alaska Range between the Kichatna and the Kuskokwim is that of a synclinorium whose center is occupied by the Mesozoic beds. The above facts all point to the conclusion that these slates are of Paleozoic age, and if a more definite assignment should be made they would probably be correlated with a part of the Tonzona group (Devonian or Silurian) of the Kuskokwim Valley. As the slates have yielded no organic remains, their age can not now be more definitely determined. It should be noted, however, that these supposed Paleozoic slates are not very different lithologically from some of the overlying Jurassic beds, and it is by no means impossible that they may be Mesozoic. They differ from the Jurassic rocks in being some-

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 67–68.

[2] Idem, p. 68.

what more altered and in the fact that the fragmental beds, such as graywackes, form only a small percentage of the bulk of the material, whereas in the Tordrillo formation the grits and sandstones are more abundant than the slates.

It has been shown that the northeastern extension of this belt would carry it parallel to the Alaska Range, and slates have been reported by prospectors in this general region. Similar rocks were observed by Eldridge along the headwaters of the Susitna, though these are associated, as will be shown, with some heavy limestone. It is probable that the slates of the Kichatna section are synchronous with some of the rocks found by Eldridge near Broad Pass, but at present no more definite correlation can be made.

The work in the Yentna region in 1911 has served to confirm the conclusion reached by Brooks—that the same slate series is continuous from the Kichatna in a northeast direction along the front of the range. Although the mapping in the Yentna region was not extended quite far enough to the northeast to connect with the area visited by Eldridge, the gap left is scarcely 10 miles in width, and it seems justifiable to presume that the slates of the Kichatna and Yentna regions are the same as those noted by Eldridge in the headwater region of Susitna River and mapped by Brooks in the report quoted above as "undifferentiated metamorphic rocks of unknown age but probably chiefly Paleozoic."

In the lack of conclusive evidence of their age the rocks of the slate and graywacke series can only be provisionally assigned to the Paleozoic or Mesozoic.

Intrusive rocks.—It has already been stated that the slate and graywacke series is cut in the higher parts of the mountains by a large intrusive mass and that dikes of various kinds are also found in many places. As these intrusives cut the slates and contain inclusions of them, they are known to be younger than the slate series. Furthermore, as intrusive rocks were nowhere seen to cut the Tertiary beds, it is concluded that the intrusives are older than the Tertiary. The description of the various types of intrusive rocks is given on pages 45–47.

TERTIARY SYSTEM.

EOCENE SERIES (COAL BEARING).

Distribution.—Between the slates and graywackes and the next younger sediments of the region, the Tertiary beds, there is a break in the geologic succession, representing a long period of time during which the slates were indurated, folded, and faulted and then intruded by great bodies of igneous rock. After the cooling of the intrusions the rocks were subjected to erosion and an unknown amount of material was removed. It is even possible that great thicknesses of rocks of various kinds were laid down over this area to be completely removed by erosion before the beginning of Tertiary

times. The relief of the Alaska Range at the end of this interval is believed to have been less sharp than at present, and broad drainage basins had probably been established, one of them in a position somewhat similar to that of the present Susitna River. The change from conditions of erosion to those of deposition was probably brought about by a gradual subsidence, which caused the materials eroded in the headwater regions of the streams to be deposited, in Eocene times, in the lower portions of the basin as estuarine, fluviatile, or lacustrine beds. These sediments now occupy considerable areas in the Yentna region, extending from the base of the high mountains toward the lowlands. Their areal distribution is shown on Plate III (in pocket), but the mapped areas indicate only those places where the Eocene beds outcrop at the surface. It is certain, however, that the Eocene deposits underlie large areas in the lowlands, where they are covered by morainal material and by recent stream gravels. Beds of this age outcrop at many places where deep stream valleys have cut through the overlying materials, as in the gorges of lower Lake Creek and Kahiltna River, so that it is justifiable to presume that the Eocene beds are continuous between these streams and extend for some distance both to the east and west of them, and also that they underlie much of the high plateau north and west of Yenlo Hills. Furthermore, exposures show their presence at many points around the borders of the great Susitna basin, as on the Skwentna opposite the mouth of Hayes River; on the lower Kichatna; along the east base of Peters Hills; between Chulitna and Susitna rivers; on lower Matanuska River, and at many points around the head of Cook Inlet. In the central portion of this basin the beds are exposed at Susitna Station, and on Yentna River about 7 miles above its mouth. A more complete knowledge of this little-known region will unquestionably show many more occurrences of these rocks, and the evidence already at hand lends strong support to the presumption that the Tertiary beds underlie much of the lower Susitna basin below the borders of the surrounding mountains.

In the territory bordering the mountains in the Yentna district the Eocene beds were deposited over a considerably larger area than that which they now occupy, to be subsequently removed by erosion. They may once have been continuous between Martin and Cache creeks, over what are now the Peters Hills, and their preservation in the northwest extensions of the field is in most places due to a favorable location protected from severe erosion by glacial ice and by streams. The edges of the areas of Eocene deposits almost everywhere show the effects of erosion, for the materials are soft and are easily removed by streams or by glacial ice. In most places it is now impossible to determine how much of the surface was formerly

The complete series of the Eocene coal-bearing beds is probably nowhere exposed in the Yentna region, and any estimates of its thickness, based on the sections examined there, are likely to fall short of the original maximum thickness of the series. In many places in the Cache Creek valley 250 to 300 feet of the beds are exposed without showing their base, and at these places erosion has without doubt removed the upper portion of the series. The most complete section examined is that on the north side of Fairview Mountain (fig. 3, p. 31), at which locality over 900 feet of Eocene beds overlain by the Tertiary gravels are exposed. As Fairview Mountain is probably near the northwest border of the area which received Eocene sediments, and as the deposition of Eocene beds is believed to have commenced in the lower parts of the Susitna-Cook Inlet depression and to have gradually extended to its borders, it is entirely possible that the series at Fairview Mountain is incomplete, lacking the lowest members represented around the borders of Cook Inlet.

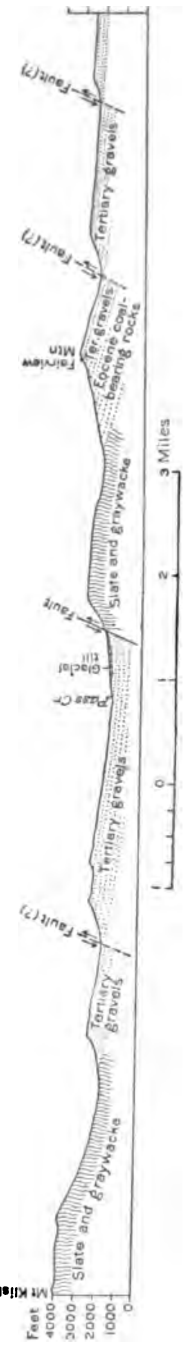


FIGURE 4.—Cross section through Fairview Mountain and Mount Kliskon, showing structural relations between the slate and graywacke series, the Eocene coal-bearing sediments, and the overlying Tertiary gravels, and the positions of known and probable faults.

Age and correlation.—The determination of the age of the coal-bearing series has been based on lithologic, stratigraphic, and paleontologic grounds. The distinctive character of the sediments, which differ from all other rocks of the region, suggests at once their correlation with the coal-bearing beds of Cook Inlet. This similarity is emphasized by the occurrence of lignitic coal in the series at both places. At Tyonek, on Cook Inlet, similar beds have been determined by Arthur Hollick and F. H. Knowlton, on the evidence of fossil plant remains, to be of Kenai age, now assigned to the Eocene. In the Yentna region, fossil plant remains were found at only a few localities, and as they occur in soft clayey shales, it was difficult to preserve them unbroken until they could be brought back for identification. In the material collected, however, enough forms were identifiable to correlate the coal-bearing series of the Yentna region definitely with the Kenai formation of

Cook Inlet. The collections were examined by Arthur Hollick, who made the following determinations:

Collection No. 1.

From Cache Creek, one-half mile above Cache Creek Mining Co.'s camp. From bed 280 feet below top of series as here exposed.

The matrix is a very friable clay. Many of the specimens were broken in fragments and of no value. The following identifications were made:

Taxodium tinajorum Heer.
Populus arctica Heer.
Corylus macquarrii (Forbes) Heer? Fragment.
Corylus? Fragments.
Alnus kiefersteinii Goepp.
Juglans acuminata Al. Braun.
Quercus pseudocastanea Goepp.
Planera ungeri Ettingsh.? Fragment.
Acer arcticum Heer? Fragmentary.
Fruit of Acer arcticum Heer?
Grewia crenulata Heer? Fragmentary.
Rhamnus, perhaps new species, like R. salicifolia Lesq.

Age, Tertiary (Eocene).

Collection No. 2.

From bed of Cache Creek, three-quarters of a mile below collection No. 1, in approximately the same horizon.

This collection consists of a single piece of hardened ferruginous clay, containing on one side poorly preserved remains of a conifer (Sequoia langsdorfii (Brongt.) Heer?) and on the other a fragmentary angiosperm leaf, possibly Corylus sp.

Age, apparently Tertiary (Eocene).

Collection No. 4.

From bed of creek in Chicago Gulch, Mills Creek basin.

Matrix, friable clay, containing one species (Betula prisca Ettingsh.).

Age, Tertiary (Eocene).

The above determinations show that the coal-bearing beds of both the Cache Creek and Mills Creek valleys are of Eocene age. More complete collections, taken from the upper and lower parts of the series, would limit more sharply the portion of Eocene time represented by these deposits, but the age determination is sufficiently definite to show that the beds were laid down at the same time that much of the Susitna basin and Cook Inlet area, as well as extensive regions in other parts of Alaska, were receiving similar deposits.

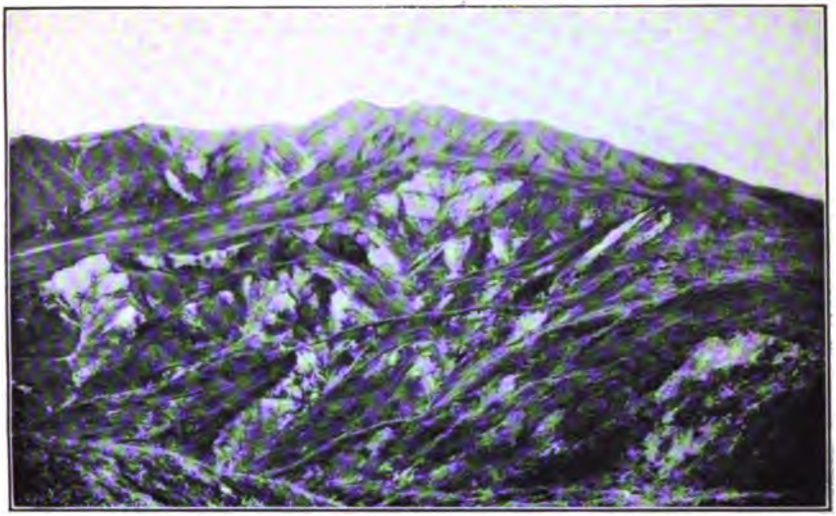
GRAVELS

Character and distribution.—At a number of localities within this district there occurs a thick deposit of coarse, stream-washed gravels lying above the sands and clays of the Eocene coal-bearing series. These gravels are best exposed in the hills between the heads of Slate and Pass creeks, and on Cottonwood Creek along the north

side of Fairview Mountain (Pl. VIII, *B*). Similar deposits exist at a number of places, including upper Treasure Creek (Pl. IX, *A*), Nugget Creek at the mouth of the canyon, and Cache Creek at the mouth of Windy Creek, but the relations of the gravels to the coal-bearing series at these localities are not clear. In the excellent exposure on the head of Slate Creek the section shows 1,100 feet of beds, composed almost entirely of coarse gravels (Pl. IX, *B*), but containing a very small proportion of finer sandy beds. The gravels are rudely stratified, as though by streams, the largest bowlders being about 1 foot in diameter, but most of the pebbles measure from 2 to 4 inches through and are mixed with much sandy material. A large variety of rocks is represented by the pebbles—slates, graywackes, black and gray conglomerates, and quartz are present, as well as diorites and many other types of igneous rocks. The deposit throughout its thickness shows a yellowish color due to oxidation, but the yellow color is evidently only a coating on the pebbles, for it has disappeared from the materials that have been rehandled by streams. The great age of these gravels is attested by their decayed condition, many of the pebbles being so rotten that they crumble and fall to pieces when disturbed, although they must have been hard and firm when they were rounded and deposited by the streams.

Structure and thickness.—Evidences of the stream-laid character of the gravels were seen at all the exposures examined. The imperfect assortment, with lenses of coarse sand and some silt, is remarkably like that seen in the deposits of the present streams. The great thickness of the beds, however, and the width of the area over which they are supposed to have once been continuous, indicate that they were laid down as a sloping plain of alluvial outwash along the flanks of the range, their original slope being a few degrees southeast. Since their deposition the gravels have been uplifted and faulted, and the present slope of the beds, though in the same direction as the original slope, is much greater, the observed dip being 11° SE. at the head of Slate Creek, decreasing away from the mountains to 5° or 6° near Pass Creek, 16° SE. on Fairview Mountain, and 5° to 6° S. on Treasure Creek. At the Pass Creek locality and on Treasure Creek the depositional angle of dip has been increased by the uplift of the mountain range, the uplift having involved the foothills also in the general elevation. The still steeper dips on Fairview Mountain are due to a strong upward movement of the rocks on the south side of the Pass Creek fault.

The original thickness of the gravels is not known, as the complete series is probably nowhere present in this district. At all the exposures examined the beds have suffered much from erosion, and a part of the series has been removed. The greatest thickness noted



A. THE EOCENE COAL-BEARING SERIES AND OVERLYING TERTIARY GRAVELS ON THE NORTHWEST SIDE OF FAIRVIEW MOUNTAIN.

The immediate foreground is composed of slate. The Eocene beds, containing lignitic coal, are overlain by Tertiary gravels, which form the upper part of the mountain.

B. TERTIARY GRAVELS ON THE SOUTHEAST SIDE OF COTTONWOOD CREEK NEAR FAIRVIEW MOUNTAIN.

Postglacial erosion has cut deep gulches in the gravels and formed an alluvial apron at their base, whereas the slate (in the foreground) shows little erosion.

A. TERTIARY GRAVELS ON THE UPPER PART OF TREASURE CREEK.

B. TERTIARY GRAVELS AT THE HEAD OF SLATE CREEK.

The hills in the distance at the right are of slate and graywacke, upon which the gravels lie unconformably.

was at the head of Slate Creek, at which place the gravels are 1,100 feet thick, measured perpendicular to the bedding (Pl. X, *A*). On Fairview Mountain measurements made in the same way show over 500 feet of gravel, as compared with 600 feet exposed on Treasure Creek. In much of the Cache Creek basin, as well as on the east side of Peters Hills and on lower Lake Creek, the gravels have been removed by erosion from above the coal-bearing sediments, if indeed they formerly overspread these beds. Little is known of their distribution or thickness in the Susitna lowland, as the surface is there covered by later glacial and stream deposits.

Age.—No fossils have as yet been found in the gravel series, so that a definite determination of its age can not now be made. In the Fairview Mountain section, where the relations of the gravels to the underlying formations could best be studied, the gravels lie directly on the Eocene coal-bearing sediments. Both were tilted to an angle of 16½°, and no structural break could be discerned between the two, the gravels seemingly having been a continuation of the Eocene sedimentation, although the conditions in the area from which the sediments were derived must have been very different from those which obtained throughout Eocene time, and the gravels may be of Eocene or later Tertiary age. The only other place at which the base of the gravels was observed is at the head of Slate Creek. At this place the gravels do not lie on the coal-bearing beds but on the older slates, and the contact is plainly unconformable. A short distance down Slate Creek, however, the coal-bearing beds outcrop beneath the gravels, so that the contact between the gravels and the slates represents a depositional overlap, an extension toward the mountains of the gravel area beyond the basin in which the coal-bearing beds were laid down.

The relations between the gravels, the coal-bearing beds, and the underlying rock at Fairview Mountain are remarkably similar to conditions which have previously been studied in the Bonnifield region, on the north side of the Alaska Range in Nenana River basin. This region was first described by Prindle,[1] who visited it in 1902 and again in 1906, and was later studied by the writer, in 1910. A comparison between figure 3 of this report and the section in the Nenana basin[2] shows that in both places the Eocene coal-bearing beds lie unconformably on a much older rock formation and are succeeded above with structural conformity by a heavy gravel series. The structure of the gravels is remarkably alike in both places, the only noticeable difference being in the composition of the pebbles, as they were derived from widely separated localities. In both

[1] Prindle, L. M., The Bonnifield and Kantishna regions: Bull. U. S. Geol. Survey No. 314, 1907, pp. 221-222.

[2] Capps, S. R., The Bonnifield region, Alaska: Bull. U. S. Geol. Survey No. 501, 1912, fig. 3, p. 58.

localities the beds have been tilted and dip away from the mountains. In the Bonnifield region, near Wood River, the writer found the Nenana gravel lying unconformably on coal-bearing beds, but there was no evidence that these beds represented the top of the coal-bearing sediments, and the unconformity might be only a local variation, and the succession from the coal series to the gravels continuous, both structurally and chronologically, throughout most of the area. The writer was inclined to believe that in the Bonnifield region there was a time break between the coal series and the gravels. A later study of the Yentna region, where structural conformity exists between the Eocene coal-bearing series and the gravels, has shaken this conclusion and given additional weight to the view held by Prindle that if the two series of deposits were separated by a time interval at all it was relatively short.

It has been shown that the gravel series is younger than the Eocene coal-bearing beds. The next younger deposits seen are of glacial origin, probably of Pleistocene age, and these in many places overlie the gravels. Furthermore, the gravels and the coal-bearing sediments are cut along Pass Creek valley by a fault which displaced the beds some thousands of feet. (See fig. 4.) The high slate scarp of this fault, on the southeast side of the valley, was overridden by ice at the time of the maximum glaciation and was smoothed and sculptured by the glacier into characteristic and unmistakable forms. There has been no considerable movement along this fault since the disappearance of the glacial ice. If, then, a fault of some thousands of feet displacement had taken place before glacial times, it appears evident that the gravels cut by this fault must be considerably older than Pleistocene, and this conclusion is supported by the advanced stage of oxidation and decay of the gravels, as compared with the deposits of known glacial origin.

It can therefore be stated definitely that the gravel series is older than the time of the last great glaciation and is younger than the Eocene coal-bearing beds. Its stratigraphic conformity with the Eocene deposits, both in this region and in other parts of the Alaska Range, seems to justify its assignment to the Tertiary.

QUATERNARY SYSTEM.

PREGLACIAL CONDITIONS.

The elevation of the area now occupied by the Alaska Range, which rejuvenated the streams and caused them to build the gravel outwash plains along the mountain foot, continued after the gravels described in the preceding pages had been deposited and in time affected also the foothill areas which had previously received a gravel covering. This widespread uplift ultimately caused the larger streams to intrench themselves in the gravel filling in great valleys

running at right angles to the axis of uplift. The movement tilted the gravels in some places and folded or faulted them in others. How long this elevation continued, or whether or not it is even now completed, is not known, but it is believed that the more important topographic features, such as the main mountain range, the foothill ridges, and the larger river valleys were all developed by the end of Tertiary time. In the details of surface configuration, however, the appearance of the region must have been greatly different from that of to-day. The land forms had been developed chiefly by weathering and by stream erosion, and the valleys were no doubt of the usual stream-cut type, V-shaped in cross section, and with interlocking spurs. There must also have been great accumulations of talus at the base of the steep slopes and of deeply decayed rock and soil in the regions of less relief.

GLACIAL EPOCH.

ADVANCE OF THE ICE.

The glacial epoch was inaugurated by a decided change in climatic conditions, either a lowering of the temperature, an increase in precipitation, or a combination of the two. At any rate, there was a gradual accumulation of snow in favorable situations, probably taking place first on the peaks of the highest mountains. As each winter added its quota of unmelted snows the snow fields became of wider extent and of greater thickness, until sufficient ice had accumulated in the valley heads to form small glaciers and start glacial movement. These smaller glaciers gradually extended down their valleys, joining in the main drainage lines to form great ice tongues.

Whether or not there was more than one important stage of glaciation in the Alaska mountains is still uncertain. Recent studies in the high mountains of Colorado have shown that there were at least two, and probably three, distinct glacial advances, separated from one another by long periods of time, and that the first one was much more extensive than the last two, the evidences of which are distinct and unquestionable. In the Yentna region, as well as in other parts of the Alaska Range, the last great ice advance was so extensive that it destroyed or covered up all deposits of earlier glaciations, if they existed there, and although future detailed work may prove that there have been earlier glacial periods in Alaska, there are as yet no data on which such an assumption can properly be based.

The glaciers, as they grew and advanced farther and farther from the valley heads, were able by their erosive action to profoundly alter the topography of their basins. They removed first the loose soil, talus, and residual materials and then attacked the hard surfaces that they had uncovered. Heavy, constantly

glaciers shod with rock fragments are agents admirably adapted to remove any obstructions which may oppose their advance or restrict their channels. They removed all hills, projecting spurs, and other irregularities of their beds, and changed the normal V-shaped cross section of stream-cut valleys in high mountains to the broad U shape characteristic of glacially sculptured basins. In this region the most conspicuous examples of straight, steep-sided U-shaped valleys are those of Yentna, Kahiltna, and Tokichitna rivers, though there are great numbers of smaller but no less perfectly developed glacial troughs, both in the foothills and on the flanks of the main range.

EXTENT OF GLACIATION.

That the glaciers in this region were formerly of much greater extent than now is shown by the distribution of glacial deposits and by the topography of the area over which the ice spread. It has long been known that Susitna basin was once occupied by a great glacier which reached tidewater in Cook Inlet. Brooks[1] has noted the presence of glacial till along the shores of Cook Inlet and has stated that the ice moved far down this depression, it being possible that the glacier terminated not far from the mouth of the inlet. It received ice from the mountains of Kenai Peninsula and from the Chigmit Mountains west of Cook Inlet, and important tributary ice streams came down Turnagain Arm and the Matanuska Valley, but the great supply of ice must have come from the high mountains which surround the Susitna basin. Glacial deposits are also known to exist throughout the area of Copper River basin and in the broad depression along the upper Susitna between Copper and Susitna basins, so that a great connected ice field must at one time have occupied all of the area between the coastal mountains and the Alaska Range, broken only by the high mountain masses which projected above its surface. There was at that time a continuous glacier reaching from Broad Pass to the head of Cook Inlet and an unknown distance down it. It certainly had a length of 200 miles and may have been over 300 miles long. All the lowland area of the Yentna region was covered by this glacier. Brooks[2] has noted glacial terraces along Kichatna River, at an elevation of 2,400 feet, which he considers to mark the upper limit of glaciation at that place. On Yenlo Hills, however, at a point farther from the mountains that supplied the ice, glacial erratic bowlders were found at an altitude of 3,300 feet, and the rounded and smoothed form of the hills indicates that the glacier overrode all of this ridge, except possibly the highest peak, so that its surface there had an elevation of at least 3,600 feet.

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[1] Brooks, A. H., The Mount McKinley region: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 126-127.
[2] Idem, p. 127.

Fairview Mountain, about 3,000 feet high, has foreign bowlders on its top. In the valley of Granite Creek, a tributary of the Kahiltna, there are definite evidences of glaciation at an altitude of 4,200 feet. It therefore seems reasonable to attribute the rounded outlines and smooth crest line of Peters Hills and of most of the Dutch Hills south of Peters Creek to the erosive action of an overriding ice sheet. There the Dutch Hills reach elevations of 4,600 feet, and it may be that the crest of the ridge rose above the level of the surrounding ice sheet, but if so it was probably covered by a dome of ice which originated upon it. Peters Hills barely exceed 4,000 feet in height and were probably overridden by the glacier. The chief lines of glacial movement were from northwest to southeast, along the Yentna, Kahiltna, and Tokichitna valleys, as far as the east front of the foothills, where the ice joined the southward-moving ice sheet in Susitna basin. On the flanks of the main range the surface of the glacier, at the time when the glaciation was most intense, stood at an elevation of about 4,000 feet. The ice then probably had a thickness of 3,600 feet in Yentna valley at the forks of the river, 2,600 feet on the plateau between the Yenlo Hills and Fairview Mountain, 3,500 feet in Kahiltna Valley at the mouth of Cache Creek, and 2,000 feet at the mouth of Nugget Creek. It is believed that glacial ice from the Tokichitna Valley flowed to the southwest through the basin of Cache Creek and through the divide from Bear into upper Peters Creek.

There is a strong contrast between the development reached by the ice on the south and east sides of the Alaska Range and that reached on the inland front of this range. Brooks[1] records that in the Kuskokwim basin the ice moved from the mountains far out into the lowland and that northwest of Mount McKinley it probably reached as far as Lake Minchumina, a distance of about 65 miles from its source. In the Bonnifield region, between Nenana and Delta rivers, the writer[2] found that on the main drainage lines the outermost moraines lie 30 to 40 miles from the valley heads, but the glaciers failed to coalesce into any such continuous ice field as that which occupied the opposite side of the range. The much greater development of ice on the south side of the Alaska Range is probably due to the fact that in glacial time, as now, the moisture-laden winds from the Pacific dropped their burden as snow on the south slope of the mountains and were relatively dry by the time they crossed the range to the interior. Another factor which favors the Pacific slope glaciers is the greater area of their accumulating grounds. On the south slope the average distance from the crest line to the base of the main range is more than 25 miles, whereas on the north it is only half this

[1] Brooks, A. H., op. cit., p. 126.

[2] Capps, S. R., The Bonnifield region, Alaska: Bull. U. S. [illegible] pp. 36-38.

distance. The area of accumulation of those glaciers which lie on the north slope is therefore much more restricted and the glaciers are correspondingly smaller.

The erosive action of the glacial ice in the mountain valleys of the Yentna region was very great, as is shown by the perfectly developed cirques and straight, broad, U-shaped valleys. Kahiltna Valley at the lower end of the glacier lies about 1,000 feet below the level of the plateau on either side of it, and glacial scour was certainly the cause of a considerable portion of this deepening, though perhaps not of all. Yentna Valley also shows the effects of profound erosion, as does the Tokichitna Valley. In the areas between these great troughs there is evidence that glacial scour was much less severe. The broad basin between Tokichitna and Kahiltna rivers, occupied in part by Cache Creek, is floored with soft, easily eroded deposits, as is also the plateau between Yenlo Hills and Chelantna Lake. These areas were glacier covered and may have been stripped of some material, but by virtue of their protected positions escaped such vigorous grinding as that to which the main valleys were subjected. It is doubtful if the glacier removed any great quantity of sediments in the lowland or scoured the hard bedrock except at those places where hills of hard rock projected through the Eocene sediments. In the lowland in many places glacial till and stream gravels overlie soft Eocene beds, which would have been removed if erosion had been as intense as it was in the higher valleys.

RETREAT OF THE ICE.

The period of maximum glaciation was ended by a progressive change in the climate, which became less favorable for ice accumulation, so that the glaciers gradually decreased in area and thickness. This shrinking of the glaciers caused the ice tongue in Cook Inlet to retreat, and at the same time the glacier in the Yentna region became thinner. It is probable that the glacial retreat was neither rapid nor continuous but consisted of a series of recessional phases alternating with advances, the sum total of which was a gradual shrinking of the ice flood. The first rock masses to emerge from beneath the ice were the ridges of Yenlo, Peters, and Dutch hills. These were still in the area of glacial accumulation, and on them were formed local glaciers, which joined the greater ice sheet below and became longer as its border retreated. At a still later stage the ice tongues from the main valleys became separated from one another, and the plateaus between were laid bare, causing the valley glaciers in the foothills to become separated from the main ice tongues. A still further retreat brought about the withdrawal of the glaciers to their present positions and caused the complete disappearance of the glaciers in the foothills from the cirques which they had carved for themselves.

Many valleys on the flanks of the Alaska Range also became free from glacial ice.

PRESENT GLACIERS.

Yentna glaciers.—Both of the headward forks of Yentna River rise in glaciers. The mountains that surround the West Fork are comparatively low and their glaciers are small. The East Fork heads in two large glaciers, one of which seems to flow from the east slope of Mount Dall, and the other probably drains the southeast side of Mount Russell. Their upper basins are still unexplored and their area is not known. Below the junction of these two tributary valleys the main trough is wide and deep, having straight-sided walls which give evidence of the severity of the glacial scour. No large tributaries enter for some miles below the forks, though postglacial erosion has notched the valley walls with sharp canyons along some of the stream courses. At the base of the mountains the old Yentna Glacier joined the ice streams which emerged from the Nakochna, Kichatna, and Skwentna drainage basins and with them poured a broad ice flood out on the Susitna lowland.

Kahiltna Glacier.—One of the largest glaciers of the range occupies the upper portion of the Kahiltna basin. It extends to the edge of the mountains and at its lower end has a width of nearly 4 miles. Nothing is known of its length nor of the area which it drains, but from the size and position of its lower end it is evident that the supply basin is large and probably includes the southern slopes of Mount Foraker. The lower 20 miles of this glacier may be seen from favorably situated mountains along its sides, but a bend in the valley cuts off the view of the headward portion (Pl. X, *B*). Below the bend the ice stream is 2 to 3 miles wide and has a rather uniform surface slope with a low gradient. A number of small tributary glaciers join the main ice stream from either side. Ribbon-like bands of moraine that stripe the surface become broader and more conspicuous toward the lower end of the glacier, but the surface is remarkably free from morainal covering, and white ice shows all the way to the glacier foot. There is no evidence that Kahiltna Glacier is retreating at present. Spruce trees many inches in diameter grow close to the glacier front, showing that the ice is either advancing or stationary and that its terminus is now as far advanced as at any time for perhaps 200 years.

At about the position of its present terminus the old Kahiltna Glacier joined the ice flood which at that time spread along the flanks of the range and connected with the glacial outflow from Yentna and Tokichitna glaciers. For much of the lower 25 miles of its course the river now flows through a postglacial cut in the lowland deposits.

Granite and Hidden creeks flow through severely glaciated valleys which join the Kahiltna 6 and 7 miles above the end of the glacier.

They head in small ice lobes (Pl. VI, *B*), and the valleys are notable for the straight, unbroken slopes of the side walls. Dutch Creek, the next tributary south of Granite Creek, has a glaciated valley. Through this valley and that of Bear Creek there was at one time a continuous ice field between Tokichitna and Kahiltna glaciers.

Tokichitna glaciers.—Tokichitna River heads in two glaciers, the smaller of which, called Little Tokichitna Glacier, occupies a basin at the head of the main valley and drains a small area intermediate between the basins of Kahiltna and Tokichitna glaciers. The principal lobe flows from northwest to southeast and has a length of about 11 miles, but toward its head large tributaries can be seen coming in from either side, and these drain an unmapped and unknown area. For the lower 6 miles of the glacier the ice is completely concealed beneath a heavy covering of surface moraine. Trees of considerable size grow on the river bars within a few hundred feet of the edge of the glacier, so that it is evident that the glacier front has at least maintained its position for a long time, if it has not actually advanced.

Tokichitna Glacier joins the river valley from the north, 3½ miles below the source of the stream in Little Tokichitna Glacier. Its outlines have been mapped for the lower 20 miles of its course, but its headward tributaries lie in the most inaccessible portions of the range, and nothing definite is known about their size or position. It seems probable that the glacier takes the ice drainage from the southern slopes of Mount Hunter and possibly from Mount McKinley also. For its lower 15 miles it averages more than 2 miles in width and is separated by a narrow rugged ridge from another great glacier to the northeast. Its surface is moraine covered for 5 miles above the lower end. At the terminus heavy spruce timber grows close to the edge of the ice, indicating that the glacier end has probably been nearly stationary for a long period of time.

GLACIAL DEPOSITS.

Moraines.—Conspicuous terminal moraines are not common within the region here discussed, and it is probable that in its retreat the ice edge either did not remain stationary long enough to form prominent ridges or that they were later cut away and destroyed by stream erosion if they were ever formed. One of the best-developed terminal moraines seen is that which crosses Lake Creek valley just below Chelantna Lake and which forms the dam behind which the lake is ponded. Broad areas in the lowlands have a mild rolling topography, with undrained lake-filled hollows and irregular hills, and this topography was developed by the ice, perhaps first beneath the glacier, to be later modified by material dumped from the terminus during its retreat. Even the existing glaciers, which have stood at about their present positions for a long time, have failed to form extensive moraines, and

the streams have removed the morainal material almost as fast as it has been dropped by the ice. Deposits of glacial till of the ground-moraine type are widespread, and most exposures in the lowlands and in the plateau areas around the foothills show a sheet of glacial material varying from 2 or 3 to 75 feet in thickness, characterized by its lack of assortment and containing fine clays and sands mixed with large bowlders and angular pieces of rock. Striated pebbles and bowlders are particularly abundant, as the slates are easily scratched by the harder graywackes and igneous rocks.

Bench gravels.—As the former great glacier retreated it deposited beyond its edge a sheet of stream-laid gravels, consisting of the materials supplied by the ice to the glacial streams. The outwash gravels had a widespread distribution in the lowlands and in places attained great thickness. After their deposition, as the glaciers retreated still farther into the mountains, the streams were able to intrench themselves into their earlier deposits, and the outwash gravels were left as benches or terraces along the valley sides. Benches of this kind are prominent along the lower valley of the Yentna, and cover a considerable area between Yentna and Skwentna rivers, below the base of the mountains. There are also terraces of glacial outwash gravel in Kahiltna and Tokichitna valleys and in the basins of most of the smaller streams, and many exposures on the Cache Creek plateau reveal the presence of similar gravels as a surface covering. Well-defined terraces of this material are conspicuous on Peters Creek, above the mouth of Cottonwood Creek.

PRESENT STREAM GRAVELS.

All of the streams within the area that head in vigorous glaciers are now heavily loaded with detritus during the summer season of high water and have developed extensive gravel flats below the glaciers. These deposits are characterized by the coarseness of the gravels near the glaciers, the materials becoming progressively finer downstream. The overloaded streams deposit most of their burden within a few miles of the glaciers and spread in numerous branching channels over wide bare gravel bars. The channels are by no means permanent, but change constantly, old ones being filled and new ones established. In flood seasons the entire flat may be occupied by a nearly continuous sheet of water, so that vegetation establishes itself with difficulty. Yentna River is of this type. The East Fork valley is gravel floored and bare for some miles below the glacier, but below Mount Kliskon most of the coarser materials have been dropped and the bars consist for the most part of fine silts and quicksands, which offer serious difficulties for pack animals. Below the junction of the forks sedimentation is much less

rapid, and the stream maintains a much more definite channel to its mouth.

Kahiltna River has a gravelly flat which is nearly 4 miles wide at the glacier. The flat becomes narrower and the materials finer downstream, and at the road crossing the gravels are of small amount and quicksands occur in places. Below the crossing the river changes from a depositing to an eroding stream, and its channel is intrenched in a narrow valley. The Tokichitna Valley is also floored with a heavy gravel filling through the mountainous portion of its course.

Each of the smaller streams has developed a gravel flat adjusted to its size, to the amount of material supplied to it, to the gradient, and to the material through which it flows. All the stream placers now being mined are in the gravels of the smaller streams, and they are of great economic importance though of small areal distribution.

POSTGLACIAL EROSION.

As large glaciers still occupy the valleys of the higher mountains, that part of the area is still in the glacial period. The areas which were once glacier covered but from which the ice has now retreated are once more subjected to the agencies of weathering and stream erosion, and the streams are all tending to reestablish a more favorable grade for their valleys than that left by the ice. In those places where the glacier bed was overdeepened by ice scour the streams are depositing. In other places they are rapidly intrenching themselves into the hard rock or the softer materials of their basins, where the gradient has been increased by the ice erosion. Kahiltna River, for example, in its attempt to reduce its channel to grade with the Yentna has cut a deep gorge through the glacial deposits and Eocene sediments along its lower course, whereas in its upper valley it is building a wide flat of glacial outwash materials. It is probable that in preglacial time Lake Creek was a tributary of the Kahiltna. Its entire course below the lake appears to be postglacial. Above Willow Mountain the valley is shallow and narrow, but below this mountain the stream, like the Kahiltna, has intrenched itself in a narrow gorge, in places 300 feet deep. Erosion along both the lower Kahiltna and Lake Creek has been rapid on account of the steep grade of the streams and the soft character of the materials over which they flow. On the upper Yentna, Mascot, Eagle, and Independence creeks from the south, and Flag Creek from the north, have all made deep postglacial cuts in the glacially sculptured walls of Yentna Valley. Cache Creek, a tributary of Kahiltna River near its head, has been given a steep gradient by the glacial deepening of Kahiltna Valley. This has rejuvenated the stream and it has cut a gorge 50 to 300 feet deep along its course through the soft deposits of its basin. Its tributaries also have intrenched themselves, and on each of the larger of them, as well

as on the head of Cache Creek itself, there are slate canyons above the points at which the streams flow from the slates of their upper valleys to the Eocene beds of the Cache Creek plateau. Peters Creek has been similarly rejuvenated and has two canyons with slate walls, although east of Peters Hills it is intrenched in a gorge cut through Eocene deposits. Bear Creek and other tributaries of Tokichitna River are now cutting their channels rapidly as a result of the glacial deepening of Tokichitna Valley.

Aside from the rapid cutting by streams in valleys with oversteepened gradients, the effects of postglacial erosion in the region are inconspicuous. The amount of talus which has accumulated on the glaciated mountains since they became free from ice is nowhere great, and although the slates are poorly adapted to retain glacial smoothings and striation, and few of these were seen, the slopes of the hills still show strongly the glacially sculptured forms which erosion has since failed to destroy.

IGNEOUS ROCKS.

CHARACTER AND OCCURRENCE.

Within the basin drained by Kahiltna Glacier there is a large intrusive mass of granular rocks, extending far back into the heart of the Alaska Range. The gravels discharged by Yentna River and by both Tokichitna and Little Tokichitna glaciers indicate that these or similar intrusions are of wide areal extent, and it is probable that they form a large part of the high mountain area, although most of this mountain mass is till unexplored. Similar intrusive masses have been mapped by Brooks [1] and Prindle on the northwest side of the range, and the areas they observed may be continuous across the range with those of the Yentna region. This connection can by no means be considered to have been established, for there remains a belt 30 miles wide lying between the areas which have been visited, concerning the geology of which nothing is known beyond what facts can be learned from the rocks brought down by the glaciers. These rocks are for the most part of igneous origin, though minor amounts of sedimentary rocks are present, the source of which has not as yet been determined. In the Yentna region the character of the work permitted the mapping of only a portion of the outer border of the intrusive mass (Pl. III, in pocket). The line of its contact with the slate and graywacke series is irregular, projecting to the southwest along some of the valleys in such a way as to indicate that the intrusion was injected into the slates as a great dome-shaped mass. In Kahiltna Valley, however, the contact is nearly vertical. There are also many dikes

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, Pl. IX.

which cut the slates, but they are for the most part too small to be shown on a map of this scale.

The rocks of the main intrusion are of granitic textures and range in composition from granites with orthoclase feldspar predominating through granodiorites and quartz diorites to diorites in which the feldspars are largely plagioclase. The rocks are composed for the most part of quartz, alkali and lime-soda feldspar, biotite, muscovite, hornblende, and accessory minerals. Rocks of all textures from fine-grained rocks to coarse granites were seen, and a small amount of pegmatite was observed in the granite.

The dike rocks that cut the slates show wide variations in both composition and texture. Most of them are so altered as to be determinable with difficulty under the microscope, the feldspars having been replaced by calcite, but the most common type is a quartz porphyry, which probably had an original composition much like that of the diorites. Others are basic dark-colored rocks, which in their fine-grained phases are not distinguishable in the field from the graywackes.

AGE.

The facts observed in the Yentna district in regard to the age of the various intrusive rocks are insufficient for the accurate determination of the time during which the igneous activity took place. The great intrusive mass of granites and diorites is certainly younger than the slates and graywackes of the region, for it cuts these rocks and contains inclusions of them. Furthermore, the slates had already been consolidated and metamorphosed before the injection of the granitic magma, as is shown by the character of the included fragments and by the fact that, though the slates are everywhere deformed and commonly schistose, the intrusive masses show little evidence of having been submitted to deformational stresses since they were injected. On the other hand, the Eocene sediments, although occurring in areas surrounded by slates which have been intruded by dikes, were themselves nowhere observed to have been cut by intrusive rocks. The evidence available therefore points to the conclusion that the intrusives are younger than the slates and graywackes (Paleozoic or Mesozoic?) and older than the Eocene. Brooks[1] states that the granites and diorites of the Alaska Range cut rocks as young as the Middle Jurassic. In southeastern Alakaa similar granitic masses are considered by Spencer[2] to have been intruded between Lower and Upper Cretaceous time. The Wright brothers[3] concluded from their work in southeastern Alaska that

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 91.

[2] Spencer, A. C., The Juneau gold belt, Alaska: Bull. U. S. Geol. Survey No. 287, 1906, p. 19.

[3] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: Bull. U. S. Geol. Survey No. 347, 1908, p. 76.

the intrusions there are of pre-Cretaceous age and continued to at least Middle Jurassic time. In the Matanuska Valley Paige and Knopf [1] found the granitic rocks cutting beds which they believed to be of lower Middle Jurassic age, but which have more recently been determined to be Lower Jurassic. From his studies in the Iliamna region, Martin [2] makes the following statement:

> Regarding the age of at least part of the granitic rocks the evidence is conclusive even to a rather close time interval. Quartz diorite of the normal type for this region was intruded into the Upper Triassic rocks on Bruin Bay subsequent to their close folding. Near-by are broad areas of Upper Jurassic rocks which were not involved in this close folding and which were not cut by the granites. Middle Jurassic rocks are nowhere on Cook Inlet known to be cut by granitic rocks. The granites cut the porphyries and tuffs of Iliamna Bay, which are Lower Jurassic or older, and probably also cut rocks of similar lithology on Tuxedni Bay and north of Mount Douglas. From this evidence it may be concluded that the granitic rocks are certainly younger than the Triassic and older than the Upper Jurassic, and that they are probably older than the Middle Jurassic, and possibly younger than part of the Lower Jurassic.

From evidences of the age of similar rocks in various other parts of Alaska the age of the granitic intrusives of the Yentna region is provisionally assigned to late Lower Jurassic or Middle Jurassic time.

Some of the diabase and greenstone dikes which cut the slates have been deformed and metamorphosed with them and they are therefore younger than the slates but older than the granitic masses, which are little or not at all deformed. Nothing more definite is known of their age.

MINERAL RESOURCES.

GOLD PLACERS.

GENERAL FEATURES.

Placer gold was first discovered in the Yentna district in 1905, and since that year both mining and prospecting have been active. The indefatigable prospector has pushed into almost all the valleys which cut into the margin of the Alaska Range, yet it is worthy of note that the number of producing streams has received no additions since 1906 and that almost all of the production up to the present time has come from ground which was staked in those early years. It may be well to review briefly at this place the factors which have controlled the distribution of placer ground and have limited it to such small areas. These areas are confined to the so-called Cache Creek country and the Mills Creek diggings. The former includes, besides Cache Creek and its tributaries, the headwaters of Peters Creek, and

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 20.

[2] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: Bull. U. S. Geol. Survey No. 485, 1911, p. 76.

Long Creek, which flows to Tokichitna River; all of these creeks, however, lie in the Dutch and Peters hills, and in the broad depression between them, bordered on the south and north by Kahiltna and Tokichitna valleys. The Mills Creek placer mines are all in the headward basins of Mills and Twin creeks, which join and flow eastward to empty into Camp Creek, a tributary of Lake Creek.

ORIGIN AND DISTRIBUTION OF PLACER GOLD.

The factors which bear on the distribution of placer gold in paying quantities can not be adequately discussed for this region without first considering in some detail the former extent of the glaciers which reached so great a development along the Alaska Range. The glaciation of the region as a whole has already been discussed in the preceding pages, but the effects of glaciation, in so far as they influenced the distribution of placer gold, are again summarized here. The present glaciers are only remnants of a vast ice sheet which once filled the Susitna basin and extended far down Cook Inlet. This great glacier was several thousand feet thick in the lower parts of the Yentna region, perhaps completely covering the Yenlo Hills and leaving only the upper portions of the Peters and Dutch hills exposed, if indeed these two ranges were not also covered by the ice. At the time of the greatest glaciers an ice tongue moved southward through the broad valley of Cache Creek, and a portion of this glacier pushed across the Peters Hills along the valley now occupied by Peters Creek and greatly eroded and deepened this valley, which perhaps owes its existence to the erosion of glacial ice. Later, when the thickness of the vast glacial sheet had diminished somewhat, the many valleys of the foothill ranges were each occupied by a vigorous valley glacier. The erosive action of such great, slowly moving ice tongues was enormous, especially along the larger valleys which head in the high mountains, and any concentration of placer gold which may have existed in these valleys was scattered and mixed with the glacial deposits which now lie spread over the lowlands. It is only in the places which were protected by their topographic position from great ice erosion so that the preglacial placers could survive; where an unusual amount of postglacial erosion has permitted the reconcentration of the glacially scattered gold; or where erosion since the ice retreated has effected a new placer concentration, that gold in quantities sufficient to justify mining is now found. So little is known of the more rugged portions of the Alaska Range that nothing can be said of the possibility of lodes existing there which might have supplied gold to the stream gravels. In the district around Cache Creek, where the geologic conditions are known, it is a recognized fact that all of the streams which carry placer gold have their heads in valleys eroded in the slate and graywacke series. The rocks of this

series contain many veins and stringers of quartz, and, although up to the present time these have not been found to contain gold, this may be due to the small amount of prospecting for gold lodes which has been done. Some pieces of quartz float containing free gold have been found, and the sluice boxes have yielded much gold with quartz attached, even small pieces of quartz stringers with free gold, showing the slate which formed the walls of the quartz vein. As almost all the streams which cut the slates contain some gold, it appears highly probable that the placer gold has been derived from quartz veins in the slate and graywacke series. (See footnote, p. 26.)

GENESIS OF GOLD PLACERS.

The genesis of the placer gold in the Yentna district is believed to be as follows:

Under the influence of the granitic intrusive masses and their associated dikes the slate and graywacke series, which forms the bedrock along the flanks of the main range and in most of the foothills, was cut by quartz veins and stringers, some of which contained free gold. Most of the gold probably occurred in small discontinuous veins, for no valuable lodes have so far been discovered. Stream erosion in Tertiary time developed an extensive drainage system in the slate hills, concentrating in the stream beds some of the gold from the rock removed and scattering some gold through the extensive gravel deposits which were laid down along the base of the mountains. The mineralization of the slates was irregular, and though in some places the concentration of gold was sufficient to form workable placer deposits, in other valleys the rock removed contained but little gold and no placers resulted. The Eocene coal-bearing beds, which underlie the Tertiary gravels, were also deposited after the mineralization of the slates, but they consist for the most part of fine sediments and have nowhere been shown to be auriferous.

The uplift of the Alaska Range, which caused the rejuvenation of the streams and brought about the deposition of the thick gravel series that now forms the hills at the head of Mills Creek, continued after these gravels were deposited, giving them an increased dip away from the mountains. Stream cutting proceeded rapidly, and a well-developed drainage system was established. It is now impossible to reconstruct accurately this drainage system, but it is believed that the larger rivers then followed much the same courses that they do now. Yentna, Kahiltna, and Tokichitna rivers were the main drainage lines, but their smaller tributaries may have had a very different arrangement from the present.

With the approach of the time of greatest glaciation the ice tongues in the main valleys became constantly thicker and were augmented

by tributary glaciers from all the larger valleys along the mountain flanks and from the foothills, until the ice flood spread in an unbroken sheet throughout the whole Susitna lowland. At the culmination of the glacial advance the surface of the ice sheet stood at an elevation of about 4,000 feet along the base of the mountains, and perhaps completely submerged all the foothills below this level. Glacial erosion widened and deepened the main valleys to a remarkable extent, and in the smaller valleys its effects were strongly felt. All loose material and much hard rock was removed, and the placer gold was picked up and scattered through the débris which the glaciers carried, being deposited wherever the glacial material was dropped. It is this glacial scattering of the gold from the higher valleys which accounts for the widespread distribution of gold throughout the Susitna basin, but glaciers fail to concentrate the gold which they pick up, and it is only where streams have rehandled and reconcentrated the gold from the glacial deposits that it can be profitably recovered.

Though the sequence of events just given was the same throughout the Yentna district, certain special conditions in the valleys of Cache and Peters creeks account for the placer deposits in their basins. When the glaciers reached their greatest development, ice from the Tokichitna Valley overflowed its basin and moved southwest down the depression between Dutch and Peters hills. Small glaciers formed in the valleys of both of these ranges of hills and joined the ice in the Cache Creek basin. There the great ice movement from the Alaska Range was down the Kahiltna and Tokichitna valleys, at right angles to the Cache Creek trough, and the ice which lay between the Dutch and Peters hills is believed to have been relatively stagnant and to have eroded the Cache Creek trough but little. The tributary glaciers from the hills on either side, however, were vigorous, for they had steep gradients, and in their upper portions they scoured deeply into bedrock, having first removed all the loose materials, including any placer gold which had been previously concentrated in their valleys by the streams. At the points of junction with the stagnant Cache Creek glacier the tributary ice streams lost their power to erode, and most of the material which they had picked up from their upper valleys was dropped. After the retreat and disappearance of the glaciers the valleys within the hills were left bare and smooth and contained little placer gold, that which they had formerly contained having been scoured out by the ice and incorporated with the glacial materials which lay scattered over the broad Cache Creek valley. The streams now had increased gradients, for Cache Creek had a fall of 1,400 feet from the mouth of its interhill basin to the level of Kahiltna River. It therefore rapidly cut a canyon for itself through the glacial materials and into the Eocene sediments, and this gorge

grew headward until it had worked back up the main stream and the larger tributaries into the slate hills. Canyons were cut in the slate at the points where the streams crossed from the slates to the softer deposits of the Cache Creek valley. In cutting these deep channels the streams rehandled much of the material which the glaciers had dropped and reconcentrated any gold which it had contained. They also at some places cut through their old preglacial channels, which had been buried under glacial deposits, and reconcentrated the old placer gold contained in these channels. The result of all this postglacial cutting has been the redeposition of placer gold. The placers are commonly richest at the slate canyons of the streams because it was there that erosion by the valley glaciers became ineffective and much of the glacially removed gold was dropped and because in the narrow canyon bottoms the concentration has been greatest. The absence of workable placers in the upper slate valleys is due to the intensity of the glacial scouring and to the short period which the streams have had, in postglacial time, for the development of new placers by the erosion of the slate bedrock. In the lower courses of the small streams and of Cache Creek there is much workable ground, but at these places the gold is chiefly in small particles, indicating that it has been brought from the upper valleys by the streams, and the occasional recovery of coarser pieces of gold shows that the glacial materials contain some gold, even at considerable distances from the slate hills.

In the basin of Twin Creek the conditions are different, for the gulches which have yielded the placer gold are cut into the Tertiary gravels and the sands and shales of the coal-bearing series. It seems certain that the placer gold on these streams has been derived by a reconcentration of gold from the gravels of the upper part of the series. Whether or not those gravels originally received their gold from the slates is still a matter for conjecture.

DEVELOPMENTS.

PRESENT CONDITIONS.

All the streams of the Yentna district on which mining is now being carried on have been worked steadily or intermittently for several years, and no new locations of importance have been made. The most notable development of 1911 was the discovery of rich ground in an old preglacial channel on Dollar Creek. This discovery suggests the possibility of the existence of similar old channels in the benches of other near-by streams and will be discussed in the following pages. The streams which were being mined during the summer of 1911 are Cache Creek and its tributaries—Dollar, Falls, Thunder, Nugget, and Gold creeks; Peters Creek and its tributaries—Bird,

Willow, and Poorman creeks; Long Creek, in the Tokichitna basin, and Mills and Twin creeks and the small gulches which they drain.

CACHE CREEK BASIN.

FEATURES OF THE STREAMS.

Cache Creek is a rather large stream which joins Kahiltna River about 13 miles below Kahiltna glacier. Together with its larger tributaries it heads in Peters and Dutch hills, and its course lies between these hill ranges (Pl. IV, *A*) through a broad, elevated trough

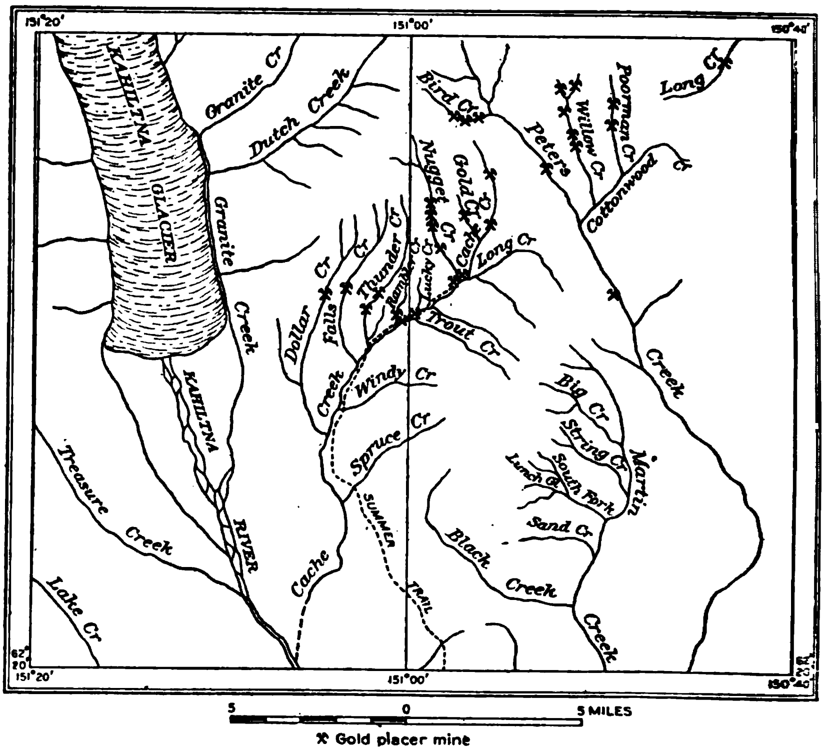

FIGURE 5.—Drainage map of Cache Creek and neighboring streams, showing location of gold-placer mines.

which is continuous from the Tokichitna to the Kahiltna, sloping gently toward the latter. Cache Creek drains the southwestern part of this trough. The many tributaries head in glaciated valleys in the hills, but on entering the broad interhill trough they pass from the slate and graywacke series, or hard bedrock, out upon the loosely consolidated beds of the coal-bearing series, which forms the so-called "soft bedrock." As Cache Creek in the upper part of its broad basin has an elevation of about 2,000 feet, and its junction with Kahiltna River is less than 600 feet above sea level, it falls 1,400 feet in 18 miles. It has therefore been able to intrench itself into the soft underlying

A. CACHE CREEK AND ITS GORGE, CUT THROUGH EOCENE DEPOSITS.

The Peters Hills, which border the basin, are composed of slates and graywackes.

B. SLUMPING GROUND ON THE NORTHWEST WALL OF THE CACHE CREEK GORGE.

A. PLACER MINING ON DISCOVERY CLAIM, CACHE CREEK.

B. SLUICING WITH HYDRAULIC GIANT ON CACHE CREEK NEAR THE MOUTH OF RAMBLER GULCH.

formation and flows through a gorge whose walls in places rise 300 feet above the creek (Pl. XI, *A*). Its tributaries also have made deep cuts where they cross the basin. Mining has been confined altogether to the main creek and to the largest tributaries, which enter the stream from the northwest. Figure 5, a sketch map of the Cache Creek and the neighboring streams, gives the location of the gold placer mines.

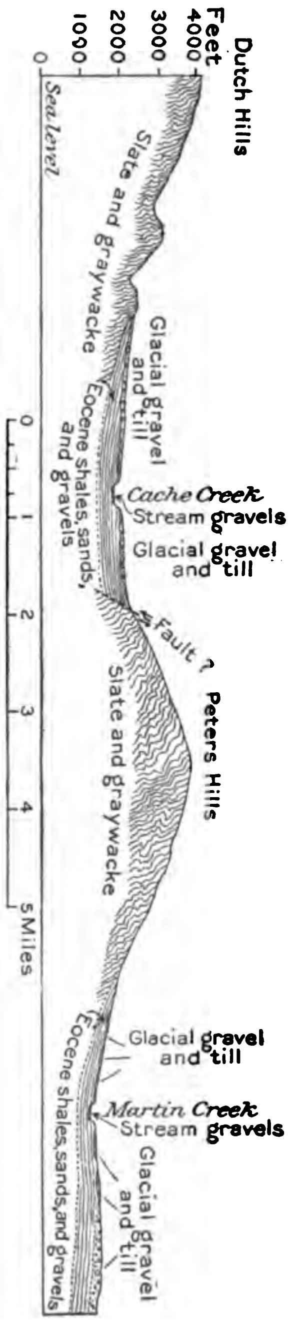

FIGURE 6.—Cross section of Dutch and Peters hills and of the basins of Cache and Martin creeks, showing structural relations of the formations.

CACHE CREEK.

Cache Creek heads in a small glacial valley in the Dutch Hills, through which it flows for only 2 miles before it emerges into the broad and wide valley which it follows to Kahiltna River. In the hills its valley is cut in the slate and graywacke series, and the stream gravels lie on "hard bedrock." Near its head the stream has eroded its valley but little in postglacial time, though for a short distance back from the base of the hills it has cut a sharp canyon into the slates. This canyon ends abruptly at the contact between the slate series and the sands and shales of the coal-bearing formation, and from this point downstream the creek, though intrenched below the level of the broad plateau, has a wider valley floor. Figure 6 shows a section drawn across both Dutch and Peters hills, indicating the structural relations of the various formations. The valley walls, or benches, are about 50 feet high at the mouth of the canyon. At the mouth of Nugget Creek the stream bed is about 250 feet below the level of the surrounding deposits, and the depth increases to nearly 300 feet between Nugget and Spruce creeks (Pl. XI, *A*). Below Spruce Creek the stream has a steep gradient through a bowlder-filled canyon, below which it reaches the Kahiltna flats.

Gold was first discovered on Cache Creek in 1906, the year after the first discoveries in this region were made on the headwaters of Peters Creek. The first ground mined was at the canyon near the head of the stream on Discovery claim, which has been worked every year since. During the summer of 1911 two men were mining a short distance below the mouth of the canyon (Pl. XII, *A*). The ground worked was that of the present stream flat, and the gravels moved range from 4 to 7 feet in depth and lie on slate bedrock. There are some large bowlders present, but most of them can be handled by one man. A short distance below the canyon the slate bedrock gives place to the materials of the coal-bearing series, which change character within short distances, ranging from a fairly firm, gritty sandstone to soft clay shales. The pay streak is said to be rather well defined in the canyon and for a short distance below it but soon spreads out in the wider valley below and is difficult to trace. The gold is rather unevenly distributed, for, though most of it is found on bedrock, the degree of its concentration depends somewhat on the character of the bedrock, the harder strata having retained it better than the softer. No records have been kept which would show the gold content of the gravels to the cubic yard or to the square yard of bedrock, but it is reported that the returns have averaged about $10 a day for each man employed. The sluice boxes, 14 inches wide, are set on a grade of 5 inches to the box length. The gravels are groundsluiced to a depth within a foot or so of bedrock by the aid of canvas hose and water under pressure from the bench to the southwest, the rest of the gravel being shoveled in and bedrock cleaned by hand. The stream at Discovery claim can be depended upon to run a sluice head of water for the boxes used throughout the season, and most of the time it flows two sluice heads. The gold is coarse, bright, and somewhat worn, though many pieces are rough and some cubes of crystalline gold have been found. Pieces worth $20 have been taken from this claim, and only about one-third of the gold recovered will pass through a 16-mesh screen.

The coarseness of the gold and the roughness of some of it indicate that it has traveled no great distance from its bedrock source. It must originally have come from the quartz veinlets of the slate and graywacke series in the upper part of the Cache Creek valley, or at the head of Bird Creek, for the upper valley at one time contained a vigorous glacier and ice also came into it from the head of Bird Creek, across a low divide. This glacier eroded its basin and doubtless scattered and removed any preglacial gold which may have been concentrated in its upper portion. No ground carrying paying quantities of gold has been discovered above the canyon of Cache Creek. Toward the mouth of the slate valley the ice scour was less severe, as the

glacier joined a large sluggish ice sheet in the broad basin between Dutch and Peters hills. Here the valley deepening was not pronounced, and a part of the material picked up by the ice in the upper valley was dropped. It may be that the glacial deposits here covered up portions of the preglacial channel of Cache Creek without disturbing them. When the glacier melted away the stream cut through the glacial deposits and at and below the canyon intrenched itself into the slates and the softer beds to the east. In the rehandling of the glacial material any gold that it contained was concentrated in the stream bed, and if the valley was cut through any undisturbed portions of the old preglacial channel these, too, would have contributed to the richness of the present placer deposits.

The possibility that remnants of the old channel still exist in the benches is suggested by several facts which have been learned during the years that mining has been carried on here. It is said that the pay streak terminates rather abruptly at its upstream end in the canyon, although some gold has been found farther upstream. In the spring of 1911 a cut was run into the high bench at the point where the pay streak failed. The bench consists of gravels lying on decayed rocks of the slate series and is overlain by 15 to 20 feet of glacial till. In groundsluicing the upper portion of this cut some gold was recovered, but most of it lay on or in bedrock. The gold was coarse, the largest nugget being worth $9. It may be that at this place there is a portion of a preglacial stream channel which contained workable placers. At the time of visit the development work on the bench was insufficient to show definitely the presence of such an old channel or to give any reliable clue as to its length or direction.

In 1911 two men were mining on Cache Creek, about a mile above the mouth of Nugget Creek. The ground worked was on the present stream flat and ranged in depth from 4 to 7 feet. The usual number of coarse bowlders was encountered, but most of them could be readily thrown from the pit. The gravels lie on "soft bedrock," composed of the clay, sand, and soft conglomerates of the coal-bearing series. At one place the creek is crossed by a bed of lignite, which held the gold and yielded good returns. The gold in the gravels is mostly found on bedrock, the richness of the ground depending to an important degree on the character of the beds crossed. In the beds of clay little gold is found, but the sandy and gravelly beds have retained the gold much better. A grade of 5 inches to the box length is maintained, this being less than the fall of the creek. The sluice boxes in use are 20 inches wide, and the creek at this point supplies enough water for them throughout the summer. Water under pressure is obtained from Columbia Gulch, a small tributary of Cache Creek from the north, and is carried by ditch over the bench to a point opposite the pit, to which it is conducted through 6-inch canvas

hose. A working head of about 75 feet is thus obtained, and a 2½-inch nozzle is used in piping the gravel into the boxes. It is reported that the returns from the season's work on this ground were not large.

In the main valley of Cache Creek mining operations were carried on at a number of points between the mouths of Nugget and Spruce creeks from 1906 to 1908. In some places the ground worked was in the present stream flat, but in others the gravels on benches along the valley sides were mined. In 1908 the Cache Creek Mining Co. was organized and purchased all of the main creek valley from a point 2½ miles below Spruce Creek to the mouth of Gold Creek, a distance of more than 12 miles, as well as a number of claims on the more important tributaries. The total holdings of the company embrace more than 3,000 acres, and extensive preparations have been made for developing the ground. A sawmill which has been built on the main creek one-half mile above the mouth of Thunder Creek, furnishes lumber for buildings, penstocks, flumes, and sluice boxes. Several thousand feet of hydraulic pipe, some as large as 34 inches in diameter, has been placed on the ground. During the seasons of 1910 and 1911 the energies of the company were in large part directed to procuring an adequate supply of water under pressure so that their ground could be mined by hydraulic methods. A ditch, originally designed to carry 1,500 miner's inches of water, was surveyed to tap Nugget Creek on claim "No. 7 above," but was only partly completed. Its connection with Nugget Creek was never made, but during the period of the spring run-off it receives a considerable volume of water from the melting snows on the Dutch Hills and on the broad high bench which it traverses. Construction on a second ditch, to carry 2,300 miner's inches of water, was pushed in 1910, and was almost completed. This ditch was to draw water from Cache Creek a short distance below the mouth of Nugget Creek and carry it for nearly 2 miles to a penstock, from which it was to be taken through a 34-inch steel pipe to the point where needed. The working head at the penstock was 120 feet, to be increased to 180 feet at the sawmill. In building this ditch some slumping ground was encountered, so that during the summer of 1911 the lower portion of the ditch was abandoned, and the water was carried from the completed portion to the so-called Pineo Bar through steel pipe.

In 1910 mining was carried on at two localities by the Cache Creek Mining Co. The upper locality, on Pineo Bar, lies about halfway between the mouths of Nugget and Thunder creeks. The ground worked is a few feet above the present level of Cache Creek, and the gravels lie on the sands, clays, and conglomerates of the coal-bearing series. In the bluffs on either side of Cache Creek the beds lie almost horizontal, but on the northwest side of the stream there has been

extensive slumping (Pl. XI, *B*), and the strata shown in the exposures of bedrock in the cut stand nearly vertical. The bench gravels here are certainly deposited on a slumped portion of the valley wall. In 1911 work was continued at this place, but nothing was learned in regard to the amount of gold recovered to the cubic yard of gravel moved.

In 1910 a portion of the bed of Cache Creek was worked at a point near the mouth of Rambler Gulch. The creek here flowed close to bedrock, and by diverting the stream from its channel during low water bedrock could be cleaned by removing only a thin layer of gravel. Gold was recovered in this locality in considerable amounts, but its distribution was irregular, depending on the character of the bedrock. Wherever the stream crossed a sandy or conglomeratic bed the gold had lodged, but the clayey beds were almost bare, the gold having passed on over them to find a more favorable resting place on the rougher bedrock. It is said that one working upstream could predict when a clayey bed was to be crossed by the exceptional richness of the sandy or gravelly portion of the bedrock just below. In 1911 a cut was run from the mouth of Rambler Creek up that stream for about 700 feet. A portion of the ground at the mouth of the creek was mined by pick and shovel, but that farther up was piped in by means of hydraulic giants. The depth of gravel was irregular, ranging from 18 inches to 10 or 12 feet, and the surface of the soft bedrock was uneven. At the stream mouth the gold was recovered from a bedrock of rather firm conglomerate, called cement rock by the miners, but farther upstream the beds of the coal-bearing series were encountered, the clayey shales predominating, together with some sandy and gravelly beds and a little lignitic coal. These beds are tilted at various angles and have evidently been affected by slumping. For the lower end of the cut water was supplied to the 3-inch nozzles from Rambler Creek with a head of about 60 feet. Later in the season water was procured from the upper end of Lucky Gulch with a head of 230 feet at Cache Creek. The dirt was piped into 24-inch boxes, set on a grade of 6 inches to the box length. At the upper end of the cut the gold is reported to have decreased and work was discontinued, the plant being shifted to a bench on Cache Creek (Pl. XII, *B*), about 400 feet above the mouth of Rambler. At this place the surface of the gravels lay about 10 feet above the level of Cache Creek and the depth to bedrock averaged about 6 feet. Large bowlders were not common in this cut, and those encountered all lay on bedrock. The value of the gold recovered is said to have averaged approximately $1.50 to the cubic yard of dirt moved.

GOLD CREEK.

Gold Creek is the uppermost tributary of Cache Creek from the north; it lies between the head of Cache Creek and Nugget Creek and is a small stream, only 1¼ miles in total length. It heads in the slate hills and its lower portion flows through a valley cut in the coal-bearing series. Gold was first discovered in 1909 near the point at which the creek passes from the slates to the softer deposits. At this point the valley is narrow and V-shaped, the gravels to be mined rarely having a width of more than 20 feet. The depth to bedrock ranges from 2 to 6 feet, the gold being found on bedrock or in the crevices of the slates, which here stand on edge. The gold is coarse and shotty, pieces up to $14 in value having been found. Its assay value is $17.81 an ounce, of which 6 cents is in silver. No mining was being done on this ground in 1911.

NUGGET CREEK.

Nugget Creek is the uppermost large tributary of Cache Creek, joining it a few miles below its head. Its source is in the Dutch Hills, through which it flows in a wide, straight, U-shaped valley, which shows strongly the erosive action of the great glacier that once occupied it. In the hills the basin of Nugget Creek is composed of the rocks of the slate and graywacke series, and the stream flows in a postglacial canyon, which is shallow toward the valley head but narrower and deeper downstream. At the point where it leaves the slate hills the creek occupies a canyon cut 200 feet into the rocks, but at the base of the hills the slates give place to the softer rocks of the coal-bearing series, and through these the stream has widened its gorge, though the valley walls are high and steep throughout the remainder of its course to Cache Creek.

Gold was first discovered on Nugget Creek in 1905, and the ground first worked was in the lower portion of the rock canyon. Since that year mining has been carried on in the valley each summer. The claims lying immediately above the mouth of the canyon, known as "Nos. 1, 2, and 3 below," have yielded the greatest part of the production, and are now practically worked out, but a considerable area of ground which is known to contain paying quantities of gold remains unworked.

During the summer of 1911 mining operations were being conducted on this creek by four different parties. The largest camp, consisting of 10 men, was on "No. 4 below," the ground worked lying a short distance below the mouth of the slate canyon (Pl. XIII, *A*). The stream gravels are 6 to 8 feet thick, and lie on the soft bedrock of the coal-bearing series. The gold is recovered principally from the gravel within a foot of bedrock and on the bedrock itself, which is of sandy or clayey material or loose conglomerate. The gold is very

A. MOUTH OF NUGGET CREEK CANYON.

The benches on the left, showing old levels of the creek, contain workable placers, as does the present bed of the creek.

B. EOCENE SEDIMENTS ON PETERS CREEK, ON THE EAST SIDE OF PETERS HILLS.

coarse, somewhat rusty, and moderately worn and smoot
gets worth $16 have been found below the canyon and in
one worth $60 was recovered. Simple mining methods are
upper portion of the gravels being groundsluiced off by
water under pressure, delivered through canvas hose, the head being 70 feet. The gravel immediately above bedrock and a portion of the bedrock itself are shoveled by hand into 14-inch sluice boxes.

Above the present stream flat, at the mouth of the canyon, portions of the former valley floor of Nugget Creek appear as terraces or benches, seven of which can be distinguished (Pl. XIII, *A*). Workable placer has been found on a number of these benches, and one bench, 170 feet above the stream, was being mined at the time of visit. The gravel here, which was 1 to 6 feet deep, lay on slate bedrock and is said to have yielded much gold. None of the benches, however, are of large size, and the amount of paying ground on them is small.

Three men were engaged in mining at the junction of claims "Nos. 1 and 2 above," at which place Nugget Creek lies in a slate canyon about 70 feet deep. The stream is crooked and its flat narrow, only small patches of gravel appearing between the creek bed and the base of the canyon walls. The ground worked ranged from 5 to 6 feet in depth and contained a good many bowlders, most of which, however, could be moved by hand. Hydraulic methods were employed for stripping away the upper portion of the gravels, the water being obtained from a small tributary on the northeast side of the creek and conducted through a ditch over a thousand feet long to a point above the cut, where it was delivered through canvas hose at a head of 70 feet. Bedrock here consists of slates and graywackes, which stand at high angles and strike in the general direction of the course of the creek. The gold is coarse and somewhat worn, and is unevenly distributed over the bedrock. Where the bedrock is rough good returns are found, but where it is smooth the gold recovered is not sufficient to pay for the handling of the ground.

On claim "No. 3 above," two men were mining on a bench which lies about 10 feet above the level of the stream. Pick and shovel methods were used for getting the lower part of the gravels into the sluice boxes after the upper portion had been removed by groundsluicing. Sluice boxes 12 inches in width were set on a grade of 8 inches to the box length, and sufficient water was had during the entire season. Most of the gold recovered was found on bedrock, which is here slate or graywacke. The gold is coarse, nuggets ranging in value from $1 to $6 being common. It is planned to build a ditch in 1912 to bring water under a head of 70 feet to the cut and to install 24-inch boxes, so that a larger quantity of ground may be handled.

Claim "No. 4 above" was purchased by a party of three men, who commenced mining in the spring of 1911. A wing dam was constructed, which diverted Nugget Creek for about 300 feet, and the bed of the creek was mined by shoveling the gravel into the sluice boxes. The ground ranges in depth from 2 to 9 feet, most of the gold being found on or near bedrock, here formed by the uptilted beds of the slate and graywacke series. Much of the gold is coarse, somewhat rusty and worn, and although some fine gold was recovered the greater part occurred in pieces worth from 10 cents to $3.50. The results of the season's work on this claim are reported to have been fairly satisfactory, and it is the intention of the owners to obtain water under pressure by building a ditch and to enlarge their sluice boxes in 1912.

Two parties were mining during the summer of 1911 on the Jumping Jack claim, in the valley of Nugget Creek close to its junction with Cache Creek. Two men were working on the south side of the creek and one man on the north side. The gravels here range from 3 to 5 feet in depth, lie on soft bedrock, and are comparatively free from large bowlders. The bedrock surface is irregular, being cut by shallow grooves which diverge like the rays of a fan, showing the old channel which Nugget Creek once followed as it left its own valley to join Cache Creek. The gold is irregularly distributed over bedrock, the ground being "spotted," as the miners say. The gold is brighter and finer than that found in upper Nugget Creek. The season's work showed the gold tenor of the gravels in lower Nugget Creek to be too low to warrant working by pick and shovel methods.

LUCKY GULCH.

About 1½ miles below the mouth of Nugget Creek a small valley known as Lucky Gulch joins the Cache Creek valley from the northwest. This valley is sharply V-shaped and has a steep gradient. It heads on the broad bench in which Cache Creek has intrenched itself. and is scarcely more than a mile long. Lucky Gulch lies exclusively within the area of the soft coal-bearing series, capped with glacial till and gravels, and throughout its length the stream flows over "soft bedrock," which is covered by only a shallow filling of stream gravels. At times mining has been done in this gulch in a small way, but its total production has not greatly exceeded $1,000. No work was being done on it at the time it was visited in 1911.

RAMBLER GULCH.

Rambler Gulch joins the Cache Creek valley three-fourths mile below Lucky Gulch from the same side. Like Lucky Gulch it is short and steep and lies altogether in coal-bearing sediments with a capping of glacial materials. In its upper portion the ground was

shallow and easily worked, and the creek bed was exhausted in the early years of the camp, a few thousand dollars in gold being recovered. In 1911 mining was resumed on the lower portion of the creek under conditions already described (p. 57).

THUNDER CREEK.

Thunder Creek heads in the slates and graywackes of the Dutch Hills, near Nugget Creek. On leaving the hills it bends to the south, following the general direction of the Cache Creek valley, and joins Cache Creek 3½ miles below the mouth of Nugget Creek. In its course below the hills it is intrenched below the level of the surrounding plateau, its valley lying for the most part in the beds of the coal-bearing series. For a portion of its length, however, it has cut through the softer sediments into a ridge of underlying slates. The bedrock, therefore, varies in different portions of the stream's course. During the summer of 1911 one man was mining on claim "No. 3 below." The gravels, which are 2 to 3 feet deep, were ground-sluiced and the lower portion was shoveled into the boxes. Bedrock here consists of the soft materials of the coal-bearing series. Some lignite outcrops in the high bluffs of the stream. The gold is bright and fairly coarse, but the pay streak is irregular and the gold content varies greatly from place to place, so that the returns are uncertain. The lower mile of Thunder Creek has been staked as an association claim, and four laymen were mining on the upper half of it. The gravels average about 5 feet in depth and contain few bowlders which a man can not roll from the pit. The bedrock is of varying character, at places being of the soft coal-bearing beds and at other places appearing to be a much weathered and decayed phase of the slate series. Sluice boxes 32 inches in width, set on a grade of 6 inches to the box length, were in use, and a 1,200-foot ditch supplied water from Thunder Creek with a head of 35 feet at the cut. Canvas hose and a nozzle were used for piping off the upper portion of the gravels, and the ground near bedrock was shoveled in by hand. The gold is bright and rough, many pieces having quartz attached, and seems to have traveled no great distance from its source. It assays $17.80 to the ounce, and the ground worked ran from $2 to $2.50 a cubic yard. Toward the end of the season the work was retarded by a shortage of water. In the fall of 1911 the ownership of this association group of claims changed hands, and the purchaser has signified his intention to install a hydraulic plant for the mining of the gravels on a more extensive scale.

FALLS CREEK.

Falls Creek is the next important tributary of Cache Creek south of Thunder Creek. It heads in the slates and graywackes of the Dutch Hills, flows in a course roughly parallel to that of Thunder Creek, and joins Cache Creek about three-fourths mile south of it. At the point where it passes from the slates to the beds of the coal-bearing series it has developed a narrow canyon and a waterfall, which suggested its name. Gold was first mined on Falls Creek in 1905, in the canyon cut through the slates, and the stream afforded considerable production for a few years. In the narrower portion of the canyon the difficulties of diverting the creek prevented mining except for a short time in the spring when the volume of the stream was small. At the time this creek was visited in 1911 two men were preparing to sluice ground on a high bench on the northeast wall of the valley, on claim "No. 3 above." A ditch 2,000 feet long, to supply water under pressure, was almost completed, but aside from a few small prospect pits no mining had yet been done.

DOLLAR CREEK.

Dollar Creek, the lowest large tributary of Cache Creek from the west, joins Cache Creek 2 miles below the mouth of Falls Creek. The geologic and topographic conditions in its basin are much like those on Thunder and Falls creeks. Dollar Creek flows from the slate hills at its head out onto the Cache Creek plateau in a sharply incised valley, which gradually becomes deeper downstream until at the mouth of the creek the valley bottom lies over 300 feet below the general level of the surrounding country. Even below the border of the Dutch Hills the slate bedrock is exposed by the stream cut for some distance out upon the plateau, showing that the old slate surface on which the soft bedrock sediments were laid down was uneven. Placer gold was discovered in this stream in 1905, and a few thousand dollars have been recovered from the stream gravels in the slate canyon since that time. In previous years, however, the gravels have yielded only moderate returns for the expense and labor required to work them. During the spring of 1911 two men began mining on claim "No. 2 above," but finding that the pay streak in the creek ended abruptly upstream, they ran a cut into the high bench on the northeast side in the hope of finding the source of the gold. In working up the valley side the miners found that slates and graywackes extended to an elevation of about 70 feet above the creek. In the creek channel the beds of the slate series are hard and firm, but toward the top they are weathered and appear as fairly soft sandstones and shales. The beds of the coal-bearing series, which are only a few feet thick, appear above the slates. Some pieces of lignite were found in the cut. Above the

soft bedrock lies a bed of stream-washed gravels from which rich pans could be obtained, as much as $2.50 being taken from a single pan. Above the stream gravels the exposure showed 20 feet of typical bowlder-studded glacial clay. At the time the place was visited too little work had been done to determine exactly the conditions at this place, but the facts gathered seem to show that the stream gravels were laid down in an old channel, perhaps a former channel of Dollar Creek, before the great glacial advance, as is shown by the overlying layer of glacial bowlder clay. It is also of interest to note that there was a good concentration of placer gold in preglacial time. The gravels in the old channel are of the same materials as are now found in the stream bed, the largest bowlders being 18 inches in diameter. The material is oxidized to a yellow color and the pebbles are somewhat decomposed, the whole being cemented into a loose conglomerate, which yields with difficulty to hydraulic methods of mining. The gold is coarse, rusty, and very angular. Some pieces, which seemed to be small nuggets, were found on close examination to consist of a large number of small colors cemented together by iron oxide. It is reported that the developments later in the summer showed that the gravels occupy a distinct channel which diverges upstream from the present valley of Dollar Creek, although it was traced for only a short distance. It is also reported that two distinct pay streaks were found in the gravels, one a few feet above the other, and that the gold was associated with much broken, angular quartz, indicating the possibility that it came from a vein at no great distance. The season's output from this mine is said to have been highly satisfactory, and preparations were being made to install a hydraulic plant so that operations could be conducted on a larger scale.

PETERS CREEK BASIN.

PETERS CREEK.

Peters Creek occupies a valley intermediate between Kahiltna and Tokichitna rivers and in its upper portion is roughly parallel to these two streams. It heads in a broad, severely glaciated, U-shaped valley in the Dutch Hills, turns at a right angle to cross the Cache Creek plateau, crosses the Peters Hills through a deep transverse trough, and enters the broad lowland of the Susitna Valley, the west edge of which it follows to its junction with Kahiltna River. Its total length is more than 35 miles. In its course through the higher parts of the Dutch Hills it flows in the bottom of the glacial trough in a channel which has been notched little or not at all into the slates and graywackes of the hills. In the more easily eroded coal-bearing beds of the Cache Creek plateau it has intrenched itself deeply in a canyon-like valley that extends headward into the slates for some

distance above the mouth of Bird Creek, and a similar canyon extends for more than a mile up Bird Creek. The downward slope of the Cache Creek plateau toward Peters Hills causes the stream valley to become shallower and wider in that direction, but on entering the valley through these hills the creek again flows through a rock canyon. This second slate canyon terminates at the east border of the Peters Hills, the stream once more flowing between valley walls of the coal-bearing series (Pl. XIII, *B*) and the banks gradually becoming lower downstream through the little-known area of the Susitna lowland to the south and east.

Gold was discovered at a number of places on Peters Creek and its affluents in 1905, and mining has been done on that creek each summer since that time. In 1911 work was in progress at two places on the main stream. At the mouth of the canyon through Peters Hills, a short distance above the point at which the stream passes from the slates onto the soft bedrock, two men were mining on a bench about 30 feet above the stream level, where a few feet of gravel lie on a slate bedrock. Water under a pressure of 70 feet, brought by ditch and canvas hose, was used for piping the gravels into the sluice boxes. The gravels contain rather abundant bowlders. At the time the place was visited some of the ground was still frozen. The gold, which is for the most part concentrated on bedrock, is coarse, flat, worn, and somewhat rusty, and gives evidence of having traveled some distance from its source. The largest nugget found weighed 9 pennyweights, and the gold assays about $17.75 to the ounce. The ground worked in 1910 was a short distance downstream from that worked in 1911, on a bench only a few feet above the stream. The bedrock at this place is a hard, rusty dike intruded into the slates. Prospect holes in the creek gravels below the canyon show placer gold on a soft bedrock, but the gradient of the creek is too low and the ground too deep to permit mining by pick and shovel methods.

The bedrock source of the gold in lower Peters Creek is still open to question, but this gold, like that in the other parts of this district, was doubtless derived from the quartz stringers in the slates and graywackes. In lower Peters Creek some of the gold may have come directly from the rocks of Peters Hills, through which the valley is cut, but as gold is found in the stream gravels above Peters Hills and up to the head of the stream it seems probable that the present placers are in large part the product of reconcentration of gold that was scoured from the upper tributaries of the stream by glacial ice, scattered throughout the valley, and again reconcentrated by postglacial erosion.

About three-fourths mile below the mouth of Bird Creek, at the lower end of the upper rock canyon of Peters Creek, two men were

near the contact of the slates with the soft bedrock. stalline intrusive rock crosses Peters Creek at this k gravels average about 6 feet in depth and the gold ntrated on or near bedrock. At the time the creek 1911 little ground had been mined, but the claims outh of the canyon and Bird Creek are said to have thousand dollars altogether.

BIRD CREEK.

of Bird Creek, a tributary of Peters Creek, lies alto- slates of Dutch Hills and is but little more than 2 miles ad is a broad cirque, which was once occupied by a vidently joined the valley of upper Cache Creek. Bird er, turns northward from this broad valley and in the its course flows through a narrow postglacial canyon. walls show excellent exposures of the slate and gray- , which are at several places cut by light-colored dikes. ed at three places in the canyon. At the upper place, th claim above the mouth of the creek, the stream flows v gorge, which is 80 feet deep. The gravel benches are deep and are of small area, as in many places the stream nyon bottom. Most of the gold mined has been recovered ng the stream with wing dams and cleaning the bedrock eam channel, much gold having penetrated a foot or two revices of the slates. The gold is coarse and rough, and out $17.90 an ounce. One man was working on this ground The gold is irregularly distributed, an exceptionally rich g succeeded up stream or down by barren ground, so that ns are uncertain.

ian was mining on claim "No. 3 above" and one on "No. 2 under conditions much like those described for claim "No. 4 The ground is 4 to 5 feet deep and is worked by ground- and shoveling. The slates are very irregularly bedded and are must be exercised in cleaning bedrock, as the gold pene- leeply into the cracks. At one place where a dike crosses the gold was found in crevices 5 feet below the stream bed. The bright and coarse, and although many pieces are worn smooth of it is rough and angular. The great drawbacks to mining e irregular distribution of the gold and the large proportion of ers in the stream gravels.

e rock walls of the canyon of Bird Creek are in many places d by a heavy layer of glacial clay from which some gold has recovered but not enough to encourage its further exploitation.

the lower half of its course it is intrenched in glacial materials and beds of the soft coal-bearing series and flows in a canyon which in places has a depth of 300 feet. In the headward portions of its basin gold has been found in many places, but in sufficient quantities to mine only in the basin of Mills Creek. In the lower intrenched portion of the valley some gold was recovered from the stream bars several years ago, but no permanent camps were established. It is reported that in 1911 one man was mining gravels on a bench 50 feet above the stream, about 12 miles from its junction with Yentna River. All the gold taken from lower Lake Creek is fine and has evidently traveled far from its source. Much of it was probably taken up by the glacial ice from the higher mountains and deposited in the glacial clays, being later reconcentrated by the stream.

MILLS CREEK BASIN.

General features.—Mills Creek is a tributary of Camp Creek from the west; Camp Creek empties into Lake Creek and drains a portion of the foothills and of the high plateau between that stream and Yentna River. In the upper portion of Mills Creek basin only the soft beds of the coal-bearing series and their associated gravels are exposed, the rocks of the slate and graywacke series which are seen in the basins of the streams of the Cache Creek region not appearing at the surface. Gold in paying quantities has been found only in the gulches of the hills that surround the two main forks of the stream. These hills were formerly covered and smoothed by the great glacier which mantled the region, but since its retreat the streams have cut considerable valleys in the easily eroded materials of which the hills are composed. Figure 7, a sketch map of the upper part of Mills Creek basin, shows the location of the gold-placer mines.

Wagner Gulch.—Gold was first discovered in this basin in 1906, in Wagner Gulch, a small tributary of Mills Creek, near its head. The gulch is steep and narrow and contains only a small stream. The ground to be mined averaged only 20 to 30 feet wide in the valley bottom and was 3 to 10 feet deep. The gold was found on a somewhat consolidated bed of gravels in the stream bed, or on the sands and clays of the coal-bearing series. It is bright in color and is flat and much worn, showing that it has been transported some distance from its bedrock source. This gulch is about mined out, as the pay streak terminated rather abruptly upstream. No work was done on it in 1911.

Chicago Gulch.—In Chicago Gulch, another tributary of upper Mills Creek, the conditions for mining are much like those on Wagner Gulch, except that the valley is smaller and steeper. The fall of the creek is about 1 foot in 6, and the stream gravels average about 20 feet in width from one valley wall to the other. Bowlders are numer-

ıs, but few are too large for one man to handle. The flow of the ıream becomes small during the later part of the summer, and sluice ɔxes 12, 10, or 8 inches wide are used, according to the supply of 'ater. The gold is coarse but flat and flaky, and few large nuggets ave been found. The pay streak in this gulch, like that on Vagner Creek, played out abruptly upstream. One man was mining n Chicago Gulch in 1911.

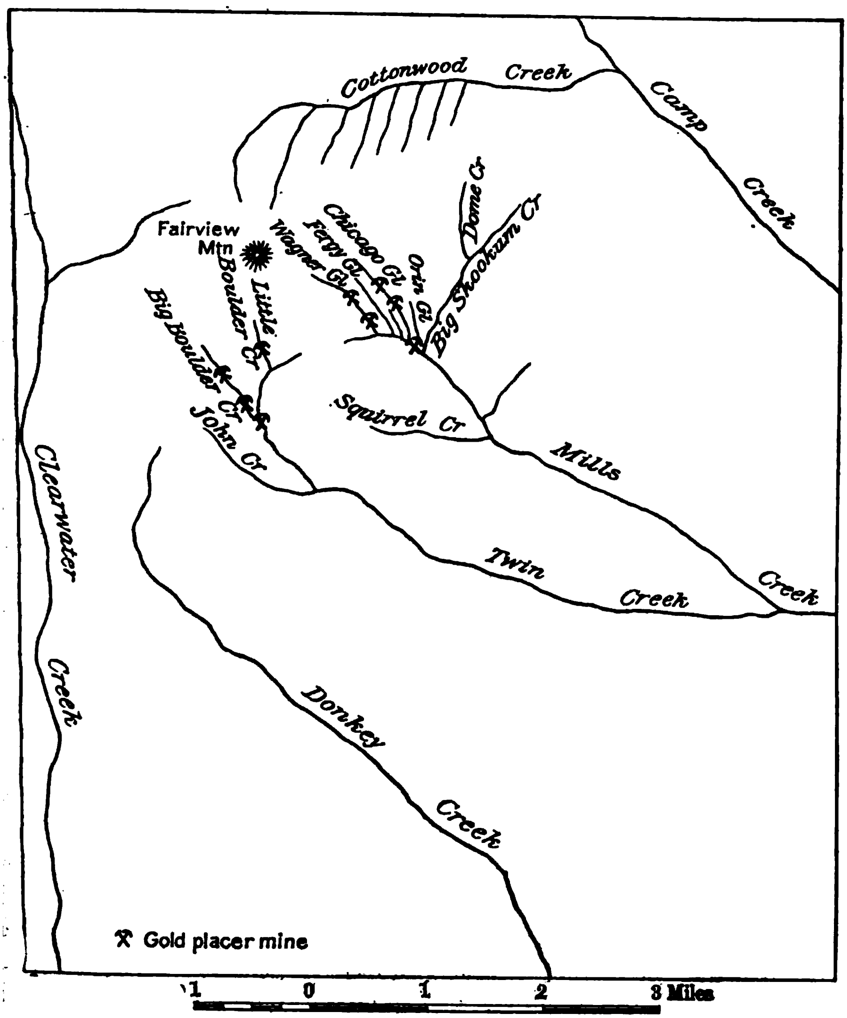

FIGURE 7.—Sketch map of upper part of Mills Creek basin, showing location of gold-placer mines.

Mills Creek.—Little work has been done on Mills Creek proper, as prospectors there have always had difficulty in reaching bedrock. The dryness of the season of 1911 put an end to mining on the smaller gulches at an earlier date than usual, and a number of men thus found

opportunity to sink a bedrock drain in the main creek valley a short distance above the mouth of Chicago Gulch. Bedrock was reached at a depth of 12 feet, and it was reported that sufficient gold to warrant mining was found.

Twin Creek.—Twin Creek forms one of the headward forks of Mills Creek, and like it lies in a basin composed solely of the gravels, sands, and clays of the coal-bearing series. Gold has been mined on three small tributaries, known as Big Boulder, Little Boulder, and Johns creeks. They are all small, steep-sided gulches cut into the soft bedrock, with steep gradients and narrow valley floors. The conditions in these gulches are like those in Wagner and Chicago gulches already described. The stream gravels have been mined for the last six years by various people, and the production, though never large, has been fairly steady.

Origin of the gold.—The bedrock in the basins of Mills and Twin creeks is quite different from that in the heads of the streams in the Cache Creek region, and the same explanation of the origin and distribution of the placer gold can not be applied to both areas. In the Cache Creek district all the producing creeks head in the slates and graywackes of the foothills ranges, or flow through materials which have come from these hills, and the gold was certainly derived from the slates. The basins of Mills and Twin creeks lie altogether in the sands and shales of the coal-bearing series and the associated gravels, and the present valleys of the streams have been eroded in post-glacial time. It seems certain, therefore, that the placer gold of the creeks was scattered through the deposits in which the streams are eroding and has been concentrated by them to form workable placer Sufficient prospecting of the materials of which the hills are composed has not been done to determine their gold content, but the manner in which the pay streaks terminate rather abruptly upstream in the several gulches suggests that most of the gold is derived from certain well-defined strata of the hills, and is found in the creeks only below the point at which these strata are crossed by the streams. The gold is flat and worn, having been rehandled by the streams. Its original source may have been the slates in the mountains to the northwest, but of this there is no definite evidence.

PROSPECTS.

In addition to the producing creeks already described, prospecting has been done on many streams of the Yentna district, some of which give considerable promise and may soon support a mining population. Kichatna River and its tributary, the Nakochna, which lie southwest of Yentna River, above the Skwentna, have been prospected by a number of men and have yielded some fine gold. It is reported that these streams afford extensive areas of gold-

ring gravels suitable for dredging. Independence Creek, a small ›utary of the Yentna below its forks, contains some gold and has n prospected for several seasons.

'he streams between Mills Creek and Kahiltna River, including np, Sunflower, and Lake Creek basins, have been prospected, and ugh gold is present on all of them no paying ground has so far ›n found. Unsatisfactory prospects have also been found on the ›ams between Dutch Hills and the main mountain range.

)n the east side of Peters Hills, on the headward tributaries of rtin Creek, coarse gold has been found, although this drainage iin has received little attention from prospectors. The geologic iditions are somewhat similar to those on the producing tributa- s of Cache Creek, and from this it would appear that this neg- ted area is at least worthy of more thorough prospecting. If the artz veins of Peters Hills carry a gold content equal to that of the ins in Dutch Hills there should be workable ground on the tributa- s of Martin Creek. On the other hand, it should be remembered at in general the mineralization of the slates decreases with distance ›m the granitic intrusions of the higher mountains, and it remains be proven whether or not the Peters Hills were sufficiently miner- zed to produce workable placers.

The recovery of considerable fine gold from the bars of Lake 'eek and Kahiltna River and reports of encouraging amounts of gold the wide flats on the lower courses of these streams give hope that some future time these streams may support a dredging industry.

SUMMARY OF PLACER MINING.

Placer gold has been mined in the Cache Creek district since 1905 id in the basin of Mills Creek since 1906. Though the region has ; no time been the scene of great activity or of large production, its ıtput has been steady and the interest in it has steadily grown reater. The population has increased from a few men in the early ears to more than 100 men in 1911, most of whom were actively ıgaged in mining or in development work. The total output up to ıe present time, as shown in the accompanying table of production, estimated at $383,000, of which about $63,000 was produced in 911.

Estimated production of placer gold from the Yentna region from 1905 to 1911.

Cache Creek	$30,000
Gold and Nugget creeks	152,000
Lucky and Rambler gulches	4,200
Thunder, Falls, and Dollar creeks	44,800
Peters and Bird creeks	28,000
Poorman, Willow, and Long creeks	106,000
Mills and Twin creeks and tributaries	15,000
Lower Kahiltna River and Lake Creek	3,000
	383,000

The estimated production of the district by years is also give[illegible] the succeeding table:

Placer production in Yentna district.

Year.	Gold.		Silver	
	Ounces.	Value.	Ounces.	Va[illegible]
1905	1,693.27	$35,000	237	[illegible]
1906	1,693.27	35,000	237	[illegible]
1907	3,434.93	71,000	481	[illegible]
1908	2,660.86	55,000	372	[illegible]
1909	2,902.75	60,000	406	[illegible]
1910	3,096.27	64,000	433	[illegible]
1911	3,047.63	63,000	427	[illegible]
	18,528.98	383,000	2,593	[illegible]

These figures should be encouraging if the lack of transporta[illegible] and the freight charge of 10 to 15 cents a pound for all supplies [illegible] equipment brought to the mines are considered. Should a railr[illegible] penetrate the Susitna Valley and reduce the time and expense [illegible] landing supplies at the camps, much ground which is not [illegible] worked could be mined at a profit and the gold output of the reg[illegible] would be greatly increased.

COAL.

The accompanying map (Pl. III, in pocket) shows the areas o[illegible] which the beds of the coal-bearing series of rocks outcrop at [illegible] surface, but it by no means indicates all the area underlain by [illegible] series, which in many places is covered by glacial materials [illegible] stream gravels. It should not be understood that all the area [illegible] mapped contains workable coal beds, for in most places the exposu[illegible] are imperfect, and only a portion of the series can be seen. At ma[illegible] localities in the Yentna district, however, there are outcrops of li[illegible] nitic coal of varying thickness. All the coal examined was of lo[illegible] grade and was light and woody in texture, with a black to browni[illegible] color, and would be classed as medium to low grade lignite. [illegible] coal has been mined commercially, and no extensive openings hav[illegible] been made which show it in an unweathered state. The best natur[illegible] exposures of coal are on Cottonwood Creek, a small stream near th[illegible] Mills Creek mining camps; on Short Creek, a small tributary [illegible] Cache Creek; and on Peters Creek below the lower canyon. A[illegible] these localities coal beds ranging in thickness from 3 to 12 feet ar[illegible] exposed. Coal taken from them has been used for fuel by miners in places where timber is scarce but has no other present commercial value.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. $1.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4–9.

The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, 1908, pp. 30–53. 45 cents.

*The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21–62. 50 cents.

The mining industry in 1909, by A. H. Brooks. In Bulletin 442, 1910, pp. 20–46.

The mining industry in 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 21–42.

*The mining industry in 1911, by A. H. Brooks. In Bulletin 520, 1912, pp. 19–44. 50 cents.

Railway routes, by A. H. Brooks. In Bulletin 284, 1906, pp. 10–17.

*Railway routes from the Pacific seaboard to Fairbanks, Alaska, by A. H. Brooks. In Bulletin 520, 1912, pp. 45–88. 50 cents.

Geologic features of Alaskan metalliferous lodes, by A. H. Brooks. In Bulletin 480, 1911, pp. 43–93.

*Tin resources of Alaska, by Frank L. Hess. In Bulletin 520, 1912, pp. 89–92. 50 cents.

*Administrative report, by A. H. Brooks. In Bulletin 259, 1905, pp. 13–17. 15 cents.

Administrative report, by A. H. Brooks. In Bulletin 284, 1906, pp. 1–3.

Administrative report, by A. H. Brooks. In Bulletin 314, 1907, pp. 11–18.

*Administrative report, by A. H. Brooks. In Bulletin 345, 1908, pp. 5–17. 45 cents.

*Administrative report, by A. H. Brooks. In Bulletin 379, 1909, pp. 5–20. 50 cents.

Administrative report, by A. H. Brooks. In Bulletin 442, 1910, pp. 5–19.

Administrative report, by A. H. Brooks. In Bulletin 480, 1911, pp. 5–14.

*Adminstrative report, by A. H. Brooks. In Bulletin 520, 1912, pp. 7–18. 50 cents.

Report on progress of public land surveys during 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 15–20.

*Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin 259, 1905, pp. 128–139. 15 cents.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.

Markets for Alaska coal, by G. C. Martin. In Bulletin 284, 1906, pp. 18–29.

The Alaska coal fields, by G. C. Martin. In Bulletin 314, 1907, pp. 40–46.

Alaska coal and its utilization, by A. H. Brooks. In Bulletin 442, 1910, pp. 47–100.

*The possible use of peat fuel in Alaska, by C. A. Davis. In Bulletin 379, 1909, pp. 63–66. 50 cents.

Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 443, 1910, 89 pp.
Geology and mineral resources of the Nizina district, Alaska, by F. H. Moffit and S. R. Capps. Bulletin 448, 1911, 111 pp.
Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts, by F. H. Moffit; including geologic and topographic reconnaissance maps. Bulletin 498, 1912, 82 pp.
The upper Susitna and Chistochina districts, by F. H. Moffit. In Bulletin 480, 1911, p. 127.
*The Taral and Bremner districts, by F. H. Moffit. In Bulletin 520, 1912, pp. 93–104. 50 cents.
*The Chitina district, by F. H. Moffit. In Bulletin 520, 1912, pp. 105–107. 50 cents.
*Gold deposits near Valdez, by A. H. Brooks. In Bulletin 520, 1912, pp. 108–1[illegible]. 50 cents.
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The Hanagita-Bremner region, Alaska, by F. H. Moffit. Bulletin —. (In preparation.)

Topographic maps.

Copper and upper Chistochina rivers; scale, 1:250,000; by T. G. Gerdine. Contained in Professional Paper 41. Not issued separately.
Copper, Nabesna, and Chisana rivers, headwaters of; scale, 1:250,000; by D. C. Witherspoon. Contained in Professional Paper 41. Not issued separately.
Controller Bay region; No. 601 A; scale, 1:62,500; by E. G. Hamilton. Price [illegible] cents a copy or $21 per hundred.
Headwater regions of Gulkana and Susitna rivers; scale, 1:250,000; by D. C. Witherspoon and C. E. Giffin. Contained in Bulletin 498. Not published separately.

COOK INLET AND SUSITNA REGION.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.
*Coal resources of southwestern Alaska, by R. W. Stone. In Bulletin 259, 1905, pp. 151–171. 15 cents.
*Gold placers of Turnagain Arm, Cook Inlet, by F. H. Moffit. In Bulletin 259, 1905, pp. 90–99. 15 cents.
*Mineral resources of the Kenai Peninsula: Gold fields of the Turnagain Arm region, by F. H. Moffit, pp. 1–52; Coal fields of the Kachemak Bay region, by R. W. Stone, pp. 53–73. Bulletin 277, 1906, 80 pp. 25 cents.
Preliminary statement on the Matanuska coal field, by G. C. Martin. In Bulletin 284, 1906, pp. 88–100.
*A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. Bulletin 289, 1906, 36 pp.
Reconnaissance in the Matanuska and Talkeetna basins, by Sidney Paige and Adolph Knopf. In Bulletin 314, 1907, pp. 104–125.
Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska, by Sidney Paige and Adolph Knopf. Bulletin 327, 1907, 71 pp.
*Notes on geology and mineral prospects in the vicinity of Seward, Kenai Peninsula, by U. S. Grant. In Bulletin 379, 1909, pp. 98–107. 50 cents.
Preliminary report on the mineral resources of the southern part of Kenai Peninsula, by U. S. Grant and D. F. Higgins. In Bulletin 442, 1910, pp. 166–178.
Outline of the geology and mineral resources of the Iliamna and Clark lakes region, by G. C. Martin and F. J. Katz. In Bulletin 442, 1910, pp. 179–200.
Gold placers of the Mulchatna, by F. J. Katz. In Bulletin 442, 1910, pp. 201–20[illegible].
The Mount McKinley region, by A. H. Brooks, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle. Professional Paper 70, 1911, 234 pp.
A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp.
Geology and coal fields of the lower Matanuska Valley, Alaska, by G. C. Martin and F. J. Katz; including detailed geologic and topographic maps. Bulletin 50[illegible], 1912, 98 pp.
*Gold deposits of the Seward-Sunrise region, Kenai Peninsula, by B. L. Johnson. In Bulletin 520, 1912, pp. 131–173. 50 cents.

*Gold placers of the Yentna district, by S. R. Capps. In Bulletin 520, 1912, pp. 174–200. 50 cents.

The Yentna district, Alaska, by S. R. Capps. Bulletin 534, 1913, 75 pp.

Preliminary report on a detailed survey of part of the Matanuska coal fields, by G. C. Martin. In Bulletin 480, 1911, p. 135.

A reconnaissance of the Willow Creek gold region, by F. J. Katz. In Bulletin 480, 1911, p. 152.

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*Kenai Peninsula, northern portion; scale, 1:250,000; by E. G. Hamilton. Contained in Bulletin 277. 25 cents. Not published separately.

Reconnaissance map of Matanuska and Talkeetna region; scale, 1:250,000; by T. G. Gerdine and R. H. Sargent. Contained in Bulletin 327. Not published separately.

Mount McKinley region; scale, 1:625,000; by D. L. Reaburn. Contained in Professional Paper 70. Not published separately.

Lower Matanuska Valley; scale, 1:62,500; by R. H. Sargent. Contained in Bulletin 500. Not published separately.

SOUTHWESTERN ALASKA.

*Gold mine on Unalaska Island, by A. J. Collier. In Bulletin 259, 1905, pp. 102–103. 15 cents.

*Gold deposits of the Shumagin Islands, by G. C. Martin. In Bulletin 259, 1905. pp. 100–101. 15 cents.

*Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin 259, 1905, pp. 128–139. 15 cents. (Abstract from Bulletin 250.)

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.

*Coal resources of southwestern Alaska, by R. W. Stone. In Bulletin 259, 1905, pp. 151–171. 15 cents.

The Herendeen Bay coal fields, by Sidney Paige. In Bulletin 284, 1906, pp. 101–108.

*Mineral resources of southwestern Alaska, by W. W. Atwood. In Bulletin 379, 1909, pp. 108–152. 50 cents.

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Outline of the geology and mineral resources of the Iliamna and Clark Lake region, by G. C. Martin and F. J. Katz. In Bulletin 442, 1910, pp. 179–200.

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The Iliamna region; scale, 1:250,000; by D. C. Witherspoon and C. E. Giffin. Contained in Bulletin 485. Not issued separately.

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*The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin 218, 1903, 71 pp. 15 cents.

*The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, by L. M. Prindle. Bulletin 251, 1905, 89 pp. 35 cents.

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*The Yukon-Tanana region, Alaska; description of the Fairbanks and Rampart quadrangles, by L. M. Prindle, F. L. Hess, and C. C. Covert. Bulletin 337, 1908, 102 pp. 25 cents.

*Occurrence of gold in the Yukon-Tanana region, by L. M. Prindle. In Bulletin 345, 1908, pp. 179–186. 45 cents.

*The Fortymile gold-placer district, by L. M. Prindle. In Bulletin 345, 1908, pp. 187–197. 45 cents.

*Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp. 25 cents.
*Water supply of the Fairbanks district in 1907, by C. C. Covert. In Bulletin 345, 1908, pp. 198-205. 45 cents.
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*The Fairbanks gold-placer region, by L. M. Prindle and F. J. Katz. In Bulletin 379, 1909, pp. 181-200. 50 cents.
*Water supply of the Yukon-Tanana region, 1907-8, by C. C. Covert and C. E. Ellsworth. In Bulletin 379, 1909, pp. 201-228. 50 cents.
*Gold placers of the Ruby Creek district, by A. G. Maddren. In Bulletin 379, 1909, pp. 229-233. 50 cents.
*Placers of the Gold Hill district, by A. G. Maddren. In Bulletin 379, 1909, pp. 234-237. 50 cents.
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Sketch of the geology of the northeastern part of the Fairbanks quadrangle, by L. M. Prindle. In Bulletin 442, 1910, pp. 203-209.
The auriferous quartz veins of the Fairbanks district, by L. M. Prindle. In Bulletin 442, 1910, pp. 210-229.
Placer mining in the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 230-245.
Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district, by B. L. Johnson. In Bulletin 442, 1910, pp. 246-250.
Water supply of the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 251-283.
The Koyukuk-Chandalar gold region, by A. G. Maddren. In Bulletin 442, 1910, pp. 284-315.
Placer mining in the Yukon-Tanana region, by C. E. Ellsworth and G. L. Parker. In Bulletin 480, 1911, p. 172.
Water supply of the Yukon-Tanana region, 1910, by C. E. Ellsworth and G. L. Parker. In Bulletin 480, 1911, p. 217.
Mineral resources of the Bonnifield region, by S. R. Capps. In Bulletin 480, 1911, p. 235.
Gold placer mining developments in the Innoko-Iditarod region, by A. G. Maddren. In Bulletin 480, 1911, p. 270.
*Placer mining in the Fortymile and Seventymile river districts, by E. A. Porter. In Bulletin 520, 1912, pp. 211-218. 50 cents.
*Water supply of the Fortymile, Seventymile, and Eagle districts, by E. A. Porter. In Bulletin 520, 1912, pp. 219-239. 50 cents.
*Placer mining in the Fairbanks and Circle districts, by C. E. Ellsworth. In Bulletin 520, 1912, pp. 240-245. 50 cents.
*Water supply of the Fairbanks, Salchaket, and Circle districts, by C. E. Ellsworth. In Bulletin 520, 1912, pp. 246-270. 50 cents.
*The Rampart and Hot Springs regions, by H. M. Eakin. In Bulletin 520, 1912, pp. 271-286. 50 cents.
*The Ruby placer district, by A. G. Maddren. In Bulletin 520, 1912, pp. 287-296. 50 cents.
*Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River, by L. M. Prindle and J. B. Mertie, jr. In Bulletin 520, 1912, pp. 201-210. 50 cents.
The Bonnifield region, Alaska, by S. R. Capps; including geologic and topographic reconnaissance maps. Bulletin 501, 1912, 162 pp.
A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp.
A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle; with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith. Bulletin 525, 1913, 220 pp.
The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp.
A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle. Bulletin 538. (In preparation.)
The Iditarod-Ruby region, Alaska, by H. M. Eakin, with geologic and topographic reconnaissance maps. Bulletin ——. (In preparation.)

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, by P. S. Smith. Bulletin 433, 1910, 227 pp.
Mineral resources of the Nulato-Council region, by P. S. Smith and H. M. Eakin. In Bulletin 442, 1910, pp. 316–352.
Mining in Seward Peninsula, by F. F. Henshaw. In Bulletin 442, 1910, pp. 353–371.
Water-supply investigations in Seward Peninsula in 1909, by F. F. Henshaw. In Bulletin 442, 1910, pp. 372–418.
A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, by P. S. Smith and H. M. Eakin. Bulletin 449, 1911, 146 pp.
*Notes on mining in Seward Peninsula, by P. S. Smith. In Bulletin 520, 1912, pp. 339–344.
Geology of the Nome and Grand Central quadrangles, Alaska, by F. H. Moffit. Bulletin 533, 1913, 140 pp.
Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology, by P. S. Smith, and a description of methods of placer mining, by Alfred H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp.

Topographic maps.

The following maps are for sale at 10 cents a copy or $3 for 50:

Casadepaga quadrangle, Seward Peninsula; No. 646 C; scale, 1:62,500; by T. G. Gerdine.
Grand Central quadrangle, Seward Peninsula; No. 646 A; scale, 1:62,500; by T. G. Gerdine.
Nome quadrangle, Seward Peninsula; No. 646 B; scale, 1:62,500; by T. G. Gerdine.
Solomon quadrangle, Seward Peninsula; No. 646 D; scale, 1:62,500; by T. G. Gerdine.

The three following maps are for sale at 50 cents a copy or $15 for 50:

Seward Peninsula, northeastern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, northwestern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, southern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.

Seward Peninsula, southeastern portion of, topographic reconnaissance of; scale, 1:250,000. Contained in Bulletin 449. Not published separately.

NORTHERN ALASKA.

*A reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. Professional Paper 10, 1902, 68 pp. 30 cents.
*A reconnaissance in northern Alaska across the Rocky Mountains, along the Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901, by F. C. Schrader and W. J. Peters. Professional Paper 20, 1904, 139 pp. 40 cents.
*Coal fields of the Cape Lisburne region, by A. J. Collier. In Bulletin 259, 1905, pp. 172–185. 15 cents.
*Geology and coal resources of Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp. 15 cents.
The Shungnak region, Kobuk Valley, by P. S. Smith and H. M. Eakin. In Bulletin 480, 1911, pp. 271–305.
The Squirrel River placers, by P. S. Smith. In Bulletin 480, 1911, pp. 306–319.
*Geologic investigations along the Canada-Alaska boundary, by A. G. Maddren. In Bulletin 520, 1912, pp. 297–314. 50 cents.
*The Alatna-Noatak region, by P. S. Smith. In Bulletin 520, 1912, pp. 315–338. 50 cents.
The Noatak-Kobuk region, by P. S. Smith. Bulletin 536. (In preparation.)

Topographic maps.

*Fort Yukon to Kotzebue Sound, reconnaissance map of; scale, 1:1,200,000; by D. L. Reaburn. Contained in Professional Paper 10. 30 cents. Not published separately.
*Koyukuk River to mouth of Colville River, including John River; scale, 1:1,200,000; by W. J. Peters. Contained in Professional Paper 20. 40 cents. Not published separately.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 535

A GEOLOGIC RECONNAISSANCE

OF A PART OF THE

RAMPART QUADRANGLE

ALASKA

BY

HENRY M. EAKIN

WASHINGTON
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1913

CONTENTS.

ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

This volume is one of a series of reports presenting accounts of the geology and mineral resources of the Yukon-Tanana region. The unit of publication is a quadrangle embracing 2° of latitude and 4° of longitude. Only that part of the Rampart quadrangle lying between Yukon and Tanana rivers has been mapped, but the report on it is here issued as one of the regular series. A report on the Circle quadrangle has been prepared, and reports on the Fortymile and Fairbanks quadrangles have been issued.[1]

These are reconnaissance reports, and the work on which they are based must be followed by more minute surveys before the details of stratigraphy and structure can be determined. It is believed, however, that they will serve a useful purpose both in outlining the general features of the geology and in affording information about the mineral resources of the region.

The publication of this series of reports will bring to a close the first stage in the investigation of the Yukon-Tanana region, which was begun in 1903 and has been continued every season until 1911. Most of these investigations were made by Mr. Prindle and his assistants, but as it was desirable to publish a report on the important gold placers of Rampart and Hot Springs at an early date and as Mr. Prindle was busy elsewhere the task was assigned to Mr. Eakin.

[1] Prindle, L. M., The Fortymile quadrangle, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 375, 1909. Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska, with a detailed description of the Fairbanks district by L. M. Prindle and F. J. Katz and an account of lode mining near Fairbanks by P. S. Smith: Bull. U. S. Geol. Survey No. 525, 1913.

A GEOLOGIC RECONNAISSANCE OF A PART OF THE RAMPART QUADRANGLE, ALASKA.

By HENRY M. EAKIN.

FIELD WORK.

The Rampart and Hot Springs gold-placer districts, together with a narrow strip on the opposite side of the Yukon, had been topographically mapped prior to the summer of 1911, during which a geologic reconnaissance of the region was made by the writer. The party, consisting of the writer and R. A. Conkling, who rendered valuable assistance throughout the season, landed at Rampart June 24. The following five weeks was spent in studying the mining districts and adjacent territory between the rivers. On August 3 the party returned to Rampart, obtained a boat, and began the study of the rocks along the Yukon below this settlement. One week was spent in making an overland trip to the head of Squaw Creek, west of the Yukon, after which the work along the river was resumed. Tanana, at the west margin of the area mapped, was reached August 16. From this date until the latter part of August the work was carried westward along the Yukon beyond the Gold Hill district, approximately to longitude 154°. (See Pl. I, in pocket, and Pl. III, p. 16.) It would have been impossible to cover so large an area in this comparatively short time had it not been for the previous work of other geologists, and acknowledgment is due to those whose published records have been freely drawn upon in the preparation of the following pages. Special assistance has been given by Mr. L. M. Prindle, who has carried on a systematic study of the Yukon-Tanana region since 1903 and whose personal suggestions have aided in working out the geologic relations of these districts to the neighboring areas on the east.

PREVIOUS INVESTIGATIONS.

In 1866 Dall[1] ascended the Yukon to Fort Yukon with a survey party of the Western Union Telegraph Co. and took notes of the geology of this part of the Yukon basin. In 1889 Russell[2] ascended

[1] Dall, W. H., Exploration in Russian America: Am. Jour. Sci., 2d ser., vol. 45, 1868, pp. 97-98; Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, p. 247.

[2] Russell, I. C., Notes on the surface geology of Alaska: Bull. Geol. Soc. America, vol. 1, 1890.

the full length of the Yukon and published valuable data on the geography and surface geology of the region. Much greater light was thrown on the geology about Rampart and along the Yukon by the more detailed studies of Spurr, Goodrich, and Schrader,[1] who in 1896 made a reconnaissance from Chilcoot Pass to Nulato. They attempted a systematic classification of the rocks along the Yukon based on their determination of the stratigraphic succession and correlated similar groups of rocks widely distributed along their route of travel; they also introduced a system of nomenclature, most of which has persisted to the present time. Their work was followed by that of Collier,[2] who in 1902 descended the Yukon, giving special attention to the coal-bearing formations, and by that of Brooks[3] and Prindle, who in the same year carried a reconnaissance from Cook Inlet to the Yukon at Rampart. Two years later Prindle and Hess[4] carried a reconnaissance from Eagle to Rampart and spent the latter part of the season in a study of the Rampart placer district. In 1907 Prindle[5] again touched the region about Rampart, and in the same year Atwood, descending the Yukon in the course of a general study of the coal-bearing terranes, spent a few days in the vicinity of Rampart.

The investigation of the water supply of the Rampart district was begun by Covert and Ellsworth[6] in 1908 and continued by Ellsworth in 1909. In addition to investigating the water supply, these engineers gathered data regarding the progress of mining in the Rampart and Hot Springs districts.[7]

GEOGRAPHY.

LOCATION AND EXTENT.

The Rampart and Hot Springs districts include most of the triangular area between Yukon and Tanana rivers west of longitude 150°, which marks the western boundary of the Fairbanks quadrangle.[8] This area, which embraces about 12,000 square miles, is part of the Rampart quadrangle, one of a system of uniform areas projected over the Territory of Alaska by the Survey to facilitate mapping

[1] Spurr, J. E., Geology of the Yukon gold district, Alaska, with a chapter on the history and present condition of the district by H. B. Goodrich: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 87-392.

[2] Collier, A. J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903.

[3] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911.

[4] Prindle, L. M., and Hess, F. L., The Rampart gold placer region, Alaska: Bull. U. S. Geol. Survey No. 280, 1906.

[5] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908.

[6] Covert, C. C., and Ellsworth, C. E., Water-supply investigations in the Yukon-Tanana region, Alaska, 1907 and 1908: Water-Supply Paper U. S. Geol. Survey No. 228, 1909, pp. 59-84, 96-98.

[7] Ellsworth, C. E., Water supply of the Yukon-Tanana region, 1909: Bull. U. S. Geol. Survey No. 442, 1910, pp. 270-281; Placer mining in the Yukon-Tanana region, 1909: Idem, pp. 239-243; Placer mining in the Yukon-Tanana region, 1910: Bull. U. S. Geol. Survey No. 480, 1911, pp. 166-168.

[8] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska, with a detailed description of the Fairbanks district by L. M. Prindle and F. J. Katz: Bull. U. S. Geol. Survey No. 525, 1913.

and description. Each quadrangle embraces 2° of latitude and 4° of longitude. This report takes account not only of all the triangular area but also of a strip of territory lying along the opposite side of the Yukon and stretching westward beyond the Gold Mountain district, or nearly to longitude 154°.

DRAINAGE.

The entire drainage of the area studied is tributary to Yukon and Tanana rivers. From the divide, which trends east and west about midway between these rivers, many streams lead northward to the Yukon and many southward to the Tanana. The strip of territory north of the Yukon, through narrow, extends back as a rule from the river to the heads of the numerous small streams tributary to the Yukon. It does not, however, embrace the whole course of Tozitna River, which enters the Yukon about 12 miles below the mouth of the Tanana. This stream, which is about 100 miles long, heads in the hills a few miles northwest of Rampart and flows parallel with the Yukon for most of its length.

Several of the smaller tributaries should be especially noted. Minook Creek, about 25 miles long, heads in the Yukon-Tanana divide and flows northward in a remarkably straight course to the Yukon near the eastern limit of the area studied. Baker Creek drains the south side of the divide opposite the basin of Minook Creek and flows into the Tanana. Its system has a peculiar broad dendritic form, being made up of a large number of evenly balanced tributaries from the east, north, and west. Patterson Creek heads against the western tributaries of Baker Creek and flows south and west to the Tanana. American Creek, a much smaller stream, rises a few miles west of the head of Patterson Creek and flows into Fish Lake. Grant Creek enters the Yukon from the north, about 15 miles below Tozitna River. All these streams are relatively small, the largest being not more than about 20 miles long. They will be mentioned later in connection with the descriptions of placer gold deposits. Little Melozi River heads against some small tributaries of the Yukon west of Grant Creek and flows first northeastward and then northward, out of the special area under consideration, to its junction with Melozitna River, which enters the Yukon about a hundred miles farther west.

RELIEF.

The topographic province to which the area under consideration belongs is the central plateau region of Alaska, which lies between the Alaska Range, nearly 200 miles south of the Rampart area, and the Endicott Range, about the same distance north.[1] This central

[1] Brooks, A. H., Geography and geology of Alaska: Prof. Paper U. S. Geol. [illegible]

plateau, however, here lacks the remarkable uniformity of elevation that characterizes it farther east, where the Yukon plateau is typically developed. Its relief is not great; the larger part of the upland of the region ranges in height from 2,000 to 3,000 feet, but peaks here and there rise to a maximum elevation of about 4,000 feet. There are local ridges that resemble those of the Yukon plateau, but they are of various elevations and most of them are only a few miles long. A somewhat uneven ridge of this type is Bean Ridge, which stretches northeastward along the Tanana to the big bend of Baker Creek. It increases in elevation gradually from either extremity to a point near Hot Springs, where it culminates in a prominent dome 2,650 feet high. The Yukon-Tanana divide has a rather even crest line from a point near the junction of the two rivers eastward to Roughtop Mountain, which rises to an altitude of about 3,000 feet. The upland area broadens east of Roughtop Mountain and numerous more or less parallel northeast-southwest ridges occupy the area between Baker Flats and the Yukon at Rampart. Many of these ridges have an elevation of approximately 2,000 feet; others of similar form rise to about 3,000 feet, and Baldry Mountain and Elephant Dome to about 4,000 feet.

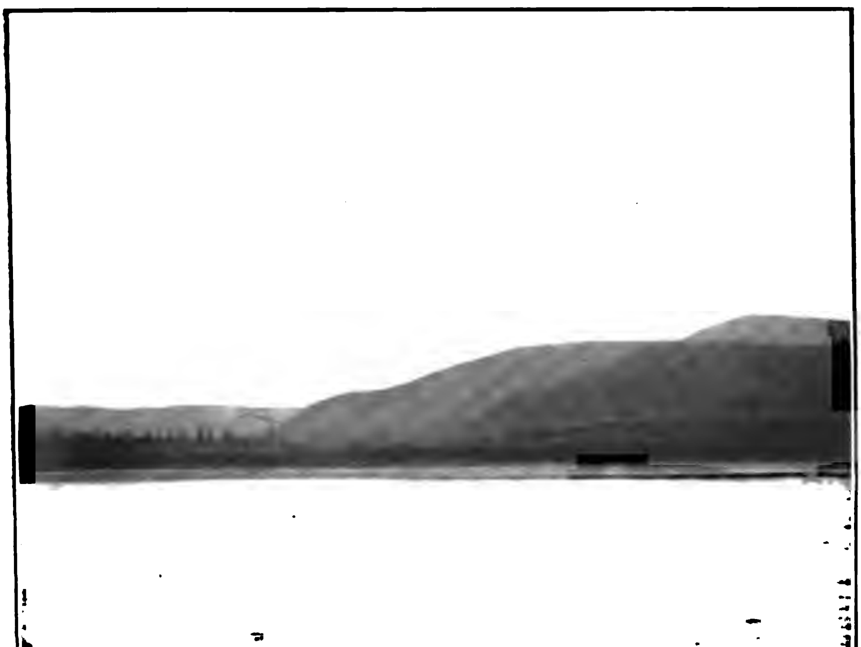
The area north of the Yukon shows even greater diversity of topographic form. On the headwaters of Tozitna River is a well-developed mountain range some of whose peaks reach altitudes of over 5,000 feet. Nearer the Yukon the elevations are lower and ridges like those between the Yukon and the Tanana occur, except in the lowlands adjacent to Tozitna River. This ridge topography extends westward along the Yukon to a point about 30 miles west of the Tozitna. Here begins another prominent range, which reaches altitudes above 4,000 feet and extends westward beyond the area studied.

Extensive lowlands stretch along the Yukon and the Tanana and along the lower courses of some of the smaller streams, as on Baker, Patterson, American, and other southward-flowing creeks of the Tanana basin, and on Tozitna River, Grant Creek, and streams farther west, flowing into the Yukon from the north. East of the Ramparts of the Yukon and parallel with them is a depression several miles wide, which is crossed by a number of small streams that head in the Yukon-Tanana divide.

Much broader, however, are the lowlands lying south of the larger streams. Seeming to be a dead-level expanse of sparsely timbered tundra, they stretch away to a horizon of low, rounded hills perhaps 60 miles south from the Yukon, and on clear days the snowy masses of McKinley, Foraker, and a great array of lesser mountains can be seen looming up at still greater distances, emphasizing the flatness of the intervening wastes. These lowlands extend eastward along the Tanana to the end of Bean Ridge and westward along the Yukon 50 miles beyond the area studied, to the mouth of the Melozitna.

A. LOWER END OF THE RAMPARTS.

Showing edge of the lowlands to the right and the hills forming the left wall of the Ramparts in the center. The chief gorge of the Ramparts is opposite the most distant hill.



B. VIEW UP MINOOK VALLEY FROM THE YUKON.

Showing broad, level-topped terraces which locally carry auriferous gravels.

The Ramparts of the Yukon are about 15 miles long and lie midway between the mouth of Minook Creek and that of the Tanana. The valley of the Yukon is here steep sided and in places canyonlike, being little wider than the stream itself and having a depth of 1,000 feet or so below the bordering hills. Disconnected remnants of terraces occur at intervals to the top of the valley walls. The high land on the right side is continuous back from the river and rises to greater altitudes than that of the immediate valley wall. On the left the river is bordered by a narrow range of hills, more or less uniform in elevation, which separates the present valley of the Yukon from the broad depression on the east. (See Pl. II, *A*.)

Tributaries join the Yukon from both sides in the Rampart reach. The smaller streams from the right enter through narrow gorgelike valleys and the larger ones commonly have broader valleys with bottom lands. The streams from the left, after traversing the broad depression, break through the narrow range of hills, some through narrow V-shaped gaps and others through broader openings corresponding with the valleys of the larger streams from the right. (See Pl. I, in pocket.)

Terraces, some rock cut and others constructional, occur at a number of places along the Yukon Valley above the Ramparts. The highest noted are at an elevation of about 1,600 feet, according closely with the top of the Ramparts, and are in the form of horizontally truncated ridges. They become more noticeable farther upstream, and near Rampart they are broadly developed in the interstream ridges of Minook Creek and its tributaries. Plate II, *B*, shows these features near the mouth of Minook Creek.

CLIMATE.

The climate of the Rampart Hot Springs districts is the same that prevails over much of interior Alaska. The winters are long and cold; the summers are short and comparatively warm. The following table gives the recorded precipitation at Rampart for the years 1906 to 1910 inclusive:

Monthly precipitation, in inches, at Rampart, 1906–1910.[a]

[Rainfall or melted snow is given in the first line, snowfall in the second line.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906	0.63	0.08	0.17	0.04	0.40	0.15	1.86	2.40	0.59	0.61	0.95	0.33	8.21
	7.2	2.0	1.8	.5	......	......	......	......	......	......	10.2	3.5	25.2
1907	1.17	.44	1.17	.02	.44	1.64	2.29	3.38	2.52	.65	.55	1.26	15.53
	12.0	4.5	12.8	2.5	......	......	......	......	......	......	6.3	......	......
1908	1.08	.52	.81	.58	.82	1.38	1.13	.46	1.56	.39	.73	1.14	10.60
	11.5	6.9	8.1	......	......	......	......	......	......	5.1	3.6	16.8	52.0
1909	.09	.10	.37	.51	1.04	.85	2.01	1.41	.36	1.14	.35	1.99	10.22
	1.4	1.2	6.2	5.6	......	......	......	......	1.5	14.4	3.6	20.2	54.1
1910	.84	.08	.36	.07	.20	.98	.71	.62	.43	.45	.26	.32	5.32
	11.1	.8	4.7	1.0	......	......	......	......	......	6.0	3.5	5.0	32.1

[a] Excerpt from table by C. E. Ellsworth, Water supply of the Yukon-Tanana region: Bull. U. S. Geol. Survey No. 480, 1911, pp. 176–177.

The average temperatures of interior Alaska are summarized by Brooks[1] as follows: "The average winter temperature in the province is 5° to 10° with a minimum of −65° to −76°; for the summer months of June, July, and August the mean is 50° to 60° and the recorded maximum 90°." A later record gives a maximum temperature of 92° on July 27, 1910, at Rampart.[2]

Concerning those phases of climate that affect transportation and mining in the interior provinces of Alaska Brooks[1] says:

Ice usually begins to run on the Yukon between the first and middle of October, but the delta closes to navigation one or two weeks earlier. In the spring the ice breaks at the mouth of the Tanana about May 10 to 15. So far as the records show, the Tanana breaks a little sooner in the spring and closes a little later in the fall than the Yukon. * * * The sluicing season in the Fairbanks district usually extends from about May 10 to the middle or end of September. There are records of creeks opening as early as the middle of April, and in 1907 most of the waterways remained open until the end of October.

Except where unusual factors operate the ground below a slight depth is permanently frozen. It remains unfrozen about Hot Springs, because of the heat of the springs, and on some of the creeks where the gravels are unusually permeable to circulating ground waters.

Summer climate is a critical factor in determining the agricultural possibilities of a country. The length of the growing season is indicated by the following table of records made at the United States Agricultural Experiment Station at Rampart:[3]

Length of growing season at Rampart.

Year.	Last spring frost.		First autumn frost.		Days between frosts.
	Date.	Temperature (°F.).	Date.	Temperature (°F.).	
1906	May 20	23	Aug. 25	25	96
1907	May 21	25	Sept. 6	24	107
1908	May 19	30	Aug. 31	29	103
1909	May 29	30	Aug. 24	27	86
1910	May 28	28	Aug. 21	27	84

VEGETATION.

Prior to its occupation by white men the region was largely covered with timber, mostly of sparse growth but locally furnishing trees suitable for mine work and lumber. Spruce is the most widely distributed species and is also the largest of the trees, attaining a diameter of 2 feet or more in especially favorable places. Birch and cottonwood are also widely distributed but attain their best growth

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 199.
[2] Gasser, G. W., Ann. Rept. Alaska Agr. Exper. Sta. for 1910, p. 44.
[3] Idem, p. 43.

only on the southward-facing slopes and on the unfrozen ground at and near Hot Springs. A few tamarack were noted on some of the tributaries of the Yukon, and willow and alder thrive on the higher slopes and along streams. Partly by use and partly by extensive forest fires the available timber has been materially reduced. It is estimated that fully four-fifths of the timbered areas have been burned over in the last decade, and during most of the summer of 1911 a number of fires were burning in different parts of the region.

Except in the densely timbered areas and natural meadows the ground is covered with the usual Alaskan carpet of mosses, grasses, herbs, low bushes, and creeping plants. Various edible berries flourish in their respective habitats. Red and black currants and raspberries are abundant in places more or less sheltered by timber; salmonberries and blueberries favor the open ground; and cranberries thrive on the sunny slopes above the timber line. In early summer the mountains are gay with lupine, gentian, wild poppy, and innumerable species of small flowering plants, the lower levels are clustered with bluebells and wild roses, and the warm hillsides, especially in burned-over areas, flame with the brilliant fireweed.

Native grasses are so generally distributed in the region that no trouble was experienced in selecting camp grounds where abundant forage was available. Redtop exceeds the other varieties in abundance and breadth of distribution. Native meadows of this grass on the Yukon bottom are annually mowed and furnish hay of good quality. A large herd of beef cattle and a number of horses were being pastured on the bottom land of the Tanana near Hot Springs, and at a number of other places horses were living on the native grasses exclusively, all keeping in excellent condition.

ANIMAL LIFE.

The largest animals native to the region are moose, caribou, and bear. Evidences of moose were observed at several places between the Yukon and Tanana, but none of the animals were seen. Caribou often range into the country during their winter migrations but are rarely seen in summer except in the mountainous areas north of the Yukon. Black and brown bear are very common, but keep mostly in the timber, and occasionally a grizzly is seen in the higher open country.

Wolves, wolverines, foxes, rabbits, marmots, martins, weasels, squirrels, and mice are among the smaller animals at home in the region, the wolves and martins being relatively scarce.

Ptarmigan and grouse are the principal game birds resident in the country the year round. Geese, ducks, cranes, and a number of smaller water fowl, shore birds, and other migrants spend the warmer months in the region.

No reptiles are known in the region. A single amphibian, a small green frog, is rather common.

Fish are abundant in all the streams that are not polluted by mining operations. The grayling and brook trout frequent even the smallest brooks. The king, silver, and dog salmon run up the larger streams annually. Pike and whitefish live in the Yukon and Tanana, and the pike is said to inhabit also some of the larger lakes.

POPULATION.

The inhabitants of the Rampart and Hot Springs districts have varied in number and have shifted from place to place with the changing fortunes of mining operations. The oldest settlements persisting at the present time are Rampart, near the mouth of Minook Creek, and Tanana, below the mouth of Tanana River. Hot Springs, on a slough of the Tanana; Glen, on a tributary of Baker Creek; and Tofty, on Sullivan Creek, have developed as supply points for the mines of the Hot Springs district. A small group of cabins and roadhouses on the bank of the Yukon near the mouth of Grant Creek is the only other white settlement in the region.

Rampart is said to have had a population of about 1,500 during its best days in 1898 and 1899.[1] Since then its population has dwindled to the present number—a little more than a score. The town of Tanana, independent of Fort Gibbon, a United States military post situated there, has a population probably fluctuating between 200 and 300. Tofty and the immediate neighborhood could number during the summer about 150 persons, but this figure would be greatly affected by any change in mining operations. The other settlements mentioned have only a few residents each—probably 50 all told.

The native population is said to be greatly reduced from its number two decades ago when few white men had visited the region. At present the principal native settlement is a mile above Tanana on the Yukon, where there are a mission and a school. There is another small village near the mouth of Tozitna River and a few natives live near Rampart.

MEANS OF COMMUNICATION.

Yukon and Tanana rivers give easy access to all parts of the region and they are navigated by a fleet of well-equipped steamboats. The freight rates from Seattle vary with the nature of the commodities and the route traversed, as indicated in the following table:

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[1] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908, p. 60.

Freight and passenger rates from Seattle to towns in the Rampart and Hot Springs districts, based on tariffs of 1910–11.

Town and route.	General merchandise per ton.	Lumber per M.	Forage per ton.		Passengers.	
			Hay.	Grain.	First class.	Second class.
Rampart:						
Via Skagway	$82–$115	$77.50	$83	$77	$111	$80
Via St. Michael	58	87.00	58	58	115	90
Tanana:						
Via Skagway	84–117	79.50	85	79	115	81
Via St. Michael	50	75.00	50	50	111	85
Hot Springs:						
Via Skagway	89–125	84.50	90	84	125	90
Via St. Michael	55	82.50	55	55	115	90

Local freight rates from river points to the creeks vary according to the condition of the roads and the season of the year. In both the Rampart and the Hot Springs districts some excellent roads are maintained. The rapid development of the Sullivan Creek placers in the last two years has made necessary additional road improvements, which were being pushed during the summer of 1911. The summer rate on goods from Hot Springs to Tofty, a distance of 12 miles, was 5 cents a pound, and considering the difficulties of the present route this charge was not unreasonable. On the completion of the route under construction the rate will probably be reduced to about the present winter rate of 1½ cents a pound.

All the river communities are in touch with the United States military telegraph. Local telephone lines give service in the Rampart and Hot Springs districts. Regular United States mail service extends to all the settlements, both winter and summer.

INDUSTRIES.

The chief industry of the region is gold-placer mining. However, a considerable part of the population is engaged in mercantile pursuits, river transportation, and freighting. Fishing, woodcutting, lumbering, and agriculture receive considerable attention. The mining industry will be treated in this report in the section on economic geology. The mercantile business of the region is limited to a rather scant fur trade and to supplying the residents with necessary commodities. The steamboat traffic on the large rivers gives employment to a number of the inhabitants of the region, both native and white. Supplies are transported from river points to the inland towns and mining camps by team and pack train, outfits for this purpose being maintained in all the river settlements. The heavy demand for dried salmon to feed dogs with during the winter leads many persons to devote themselves to the fishing industry during the annual salmon runs. The fish are usually taken by means of fish wheels set in the margins of the larger streams. Supplying wood

for fuel to the steamboats and to the towns and mining camps is a source of income for many persons. Considerable lumber is sawed in the town of Tanana, one plant being operated by the natives at their village and another at the military post. The logs are brought down Yukon and Tanana rivers in rafts and most of the lumber is used locally. The agriculture of the region is principally gardening. A small truck patch is connected with almost every establishment, whatever its nature, and at Rampart and several other places on the Yukon and at Hot Springs more extensive plots are under cultivation. At Rampart the Government maintains an agricultural experiment station under the efficient management of G. W. Gasser. This station has not only demonstrated the possibility of maturing a variety of grains and raising many kinds of vegetables but has originated a number of new varieties of these plants that are better adapted to this environment than those already existing.[1] At Hot Springs about 30 acres of unfrozen ground and about an equal area of the usual type having its subsoil permanently frozen are farmed annually. Here, in addition to the produce ordinarily grown in the region, sweet corn, cucumbers, melons, cantaloupes, and tomatoes are raised successfully, and all find a ready and profitable sale in the larger towns along the rivers. Milch cows and poultry are also kept and supply the table of the hotel, which is run in connection with the farm, with the unusual luxuries of fresh butter, milk, and eggs.

An unexpected phase of agriculture was met with at McCormick's ranch, about 12 miles below Rampart. Here potatoes are grown as food for swine. At the time of the writer's visit, August 7, the potatoes were well formed, promising a good yield, and several litters of healthy young pigs indicated the possibilities of success in the unique industry.

DESCRIPTIVE GEOLOGY.

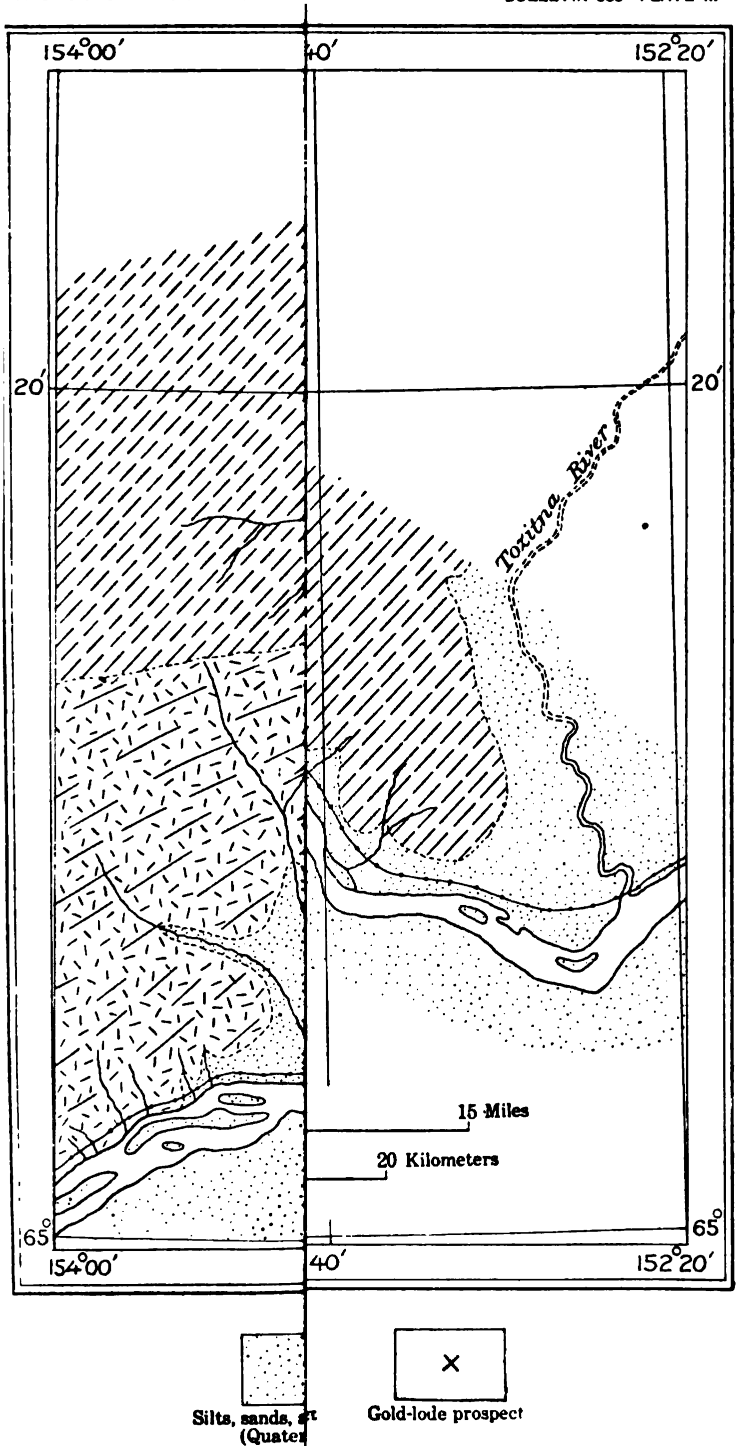
GENERAL SUCCESSION.

At the base of the geologic column in the Rampart and Hot Springs districts is a series of metamorphic rocks. They are overlain locally by Tertiary sediments and broadly by those of Quaternary age. Unaltered granitic intrusives are widely distributed in the pre-Tertiary rocks and are accompanied by a complex system of dikes, probably related to them genetically.

METAMORPHIC ROCKS.

Metamorphic rocks floor the greater part of the Rampart and Hot Springs districts and are conspicuous in all sections of the area studied. They are for the most part derivatives of original sediments but include igneous types.

[1] Georgeson, C. C., Ann. Repts. Alaska Agr. Exper. Sta. 1899-1910, Office Exper. Sta. U. S. Dept. Ag.


154°00′
40′
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20′
Toxitna River
15 Miles
20 Kilometers
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Silts, sands, &t
(Quate
Gold-lode prospect

A. CLOSE FOLDING IN LIMESTONE ON SPUR NORTH OF RUBY CREEK.

B. MASSIVE DEPOSIT OF SILT AT THE PALISADES OF THE YUKON, 25 MILES BELOW TANANA.

Differences in original constitution and in character of alteration ave resulted in a wide divergence between the types of the meta- ıorphic rocks. On account of their extremely complicated structure nd their general lack of fossils, lithology is the principal basis on vhich they can be subdivided. Four general lithologic subdivisions re recognized, each including a different set of rock types that are onstantly associated over a considerable area. (See geologic maps, Pls. III, p. 16, and IV, in pocket.) The subdivisions are (1) limestones and schists; (2) greenstones; (3) slates, sandstones, and conglomerates; and (4) slates, quartzites, and schists. The order in which these sub- livisions are mentioned here is that of their apparent stratigraphic sequence. The first is probably Silurian and Devonian, the second late Paleozoic, the third early Mesozoic, and the fourth Cretaceous and older, probably mainly Lower Cretaceous. In Plate IV some of the larger limestone areas of the oldest groups are distinguished; in this plate also some rhyolites, flows, tuffs, and breccias that are closely related to the greenstones are shown separately.

LIMESTONES AND SCHISTS (SILURIAN AND DEVONIAN?).

Limestones and schists occupy a belt from 2 to 6 miles wide along the Yukon-Tanana divide from the eastern margin of the field nearly to the junction of Yukon and Tanana rivers. They occur also in the hills of the Ramparts and are the only metamorphic rocks represented in the Gold Hill region.

The chief areas of limestone in the eastern part of the region are shown on the geologic map (Pl. IV). All these beds have suffered intense deformation, and it is highly probable that the irregularity of the limestone areas is mainly due to the aggregation in certain places of beds that were once much more evenly distributed. Plate V, *A*, shows the characteristic closely folded limestone structure. That the deformation of these rocks took place under heavy cover is shown by the common occurrence of flow structure, which is especially evident in the wavy banding of the purer marbles.

Strong metamorphism is shown by many of the limestones, especially by those of impure types. Mica is the most common secondary mineral, but garnet, epidote, and scapolite also occur. The replacement of calcite by a chertlike form of quartz is a common phenomenon, which in many places has brought about a complete change in the chemical composition of the rocks. Many of the cherts and quartzose schists are believed to represent limestones that have suffered such substitution of minerals.

The limestones of the Yukon-Tanana divide are mostly nonmagnesian, are bluish or white in color, and incline strongly toward silicification. In addition to these types buff-colored dolomitic members

occur at the Ramparts and near the head of Garnet Creek. No fossils were found in the limestones by the writer, but some were collected in 1907 by Prindle from the head of Little Minook Creek and from Quail Creek. These fossils, which were obtained from beds probably equivalent to some of those that occur along the Yukon-Tanana divide farther west, indicate Silurian and Devonian formations.

The schists include a wide variety of types. As already stated, the limestones grade into calcareous schists; quartzites and cherts grade into quartzitic and quartz-mica schists; and the slates grade into graphitic shists. Igneous rocks occurring with these schists are represented by greenstone schists, feldspathic schists, and granitic gneisses. Locally garnet and staurolite schists are developed. The metamorphism of the schistose rocks has probably been caused mainly by intense deformation of the original rocks under pressure sufficient to develop flow structure in many of the members. A complex crenulated structure in some of the schists indicates that more than one period of deformation occurred—probably most of these rocks have been affected by deformation many times.

The presence of garnet and staurolite in some of the schists is apparently due, at least in part, to the influence of the later granitic intrusives. The schists bearing these minerals are closely associated with the igneous rocks and some of them contain other minerals suggestive of contact metamorphism. The character of the schists, then, is not a fair criterion of their age. Greater weight should attach to the probable Silurian and Devonian age of the limestones, and it seems likely that in these periods most of the limestones and schists were originally deposited.

GREENSTONES (PROBABLY LATE PALEOZOIC).

In the northeastern part of the region is a large area whose predominant rocks are greenstones. This area flanks the Yukon-Tanana divide on the north, reaching from Minook Creek just above the mouth of Hoosier Creek southwestward to the Stevens Creek lowland. On the north the greenstones extend across the Yukon and beyond the head of Squaw Creek, which is the limit of the area observed.

The greenstones proper are altered basic igneous rocks, principally diabasic flows and tuffs. Associated with them in the vicinity of Rampart are minor beds of slate, chert, and limestone, besides other igneous types. Among the latter are rhyolitic lavas and flow breccias and dense aphanitic laminated rocks that apparently include glassy lavas and fine-grained tuffs. The rhyolitic rocks occupy considerable areas to the exclusion of other types, their white or buff color con-

trasting strongly with that of the greenstones. At the head of Squaw Creek the sedimentary rocks are absent and reddish andesitic flows are interbedded with the greenstones. Throughout the area of the greenstones basic igneous dikes are common, but in the Squaw Creek locality they are especially abundant. In stratigraphic position the greenstones are apparently above the limestones and schists. The nature of their relation to the underlying rocks is not clear, but they seem to record a continuance of the same activities with a marked increase in volcanism. The lowermost greenstones are interbedded with marine sediments and were probably submarine flows. The absence of such sediments among the higher members suggests that either the accumulation of the lower beds or uplift brought the area above sea level and afterward igneous activities alone were recorded. The rate of accumulation of an igneous series is capable of such wide variation that it is obviously unsafe to designate any age as that witnessing the formation of all the greenstones. It seems likely that the formation of the lower members closely followed the Devonian sedimentation. They may represent only late Devonian activities or possibly some late Devonian and more or less of the succeeding age.

SLATES, SANDSTONES, AND CONGLOMERATES (EARLY MESOZOIC).

The area lying between the Baker Creek flats and Tanana River in the southeastern part of the region is occupied by a sedimentary series. According to published descriptions[1] these rocks include red and green slates, sandstones, and fine conglomerates and although they have suffered much deformation they are but slightly metamorphosed. No fossils have been obtained from them, so their age and relations are in doubt. If they are to be correlated with a group of rocks that occurs along the north front of the Alaska Range, as suggested by Brooks,[2] they are older than Middle Devonian—probably older than the limestones and schists of the Rampart and Hot Springs districts. However, judged by their relative degree of metamorphism, they appear to be younger than the limestones and schists—younger even than the greenstones of the Rampart district. This would place them in the late Paleozoic or early Mesozoic—a view that is strengthened by the fact that the younger group next to be described, occurring in a contiguous area on the north, is largely Mesozoic and in part at least of Cretaceous age.

[1] Brooks, A. H., A reconnaissance in the White and Tanana River basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 472.

[2] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 75-76.

SLATES, QUARTZITES, AND SCHISTS (CRETACEOUS AND OLDER).

Separating the area just described from that of the limestones and schists between the Yukon and Tanana is a belt of country several miles wide, occupied by the fourth subdivision of the metamorphic series, which is composed of slates, quartzites, and schists. On the northeast these rocks extend beyond the limit of the field investigated and on the southwest they disappear beneath the alluvial lowlands of the Tanana basin. The quartzites are confined rather closely to the northern part of the belt, the slates and schists occupying much of the belt alone.

Most of the slates are dark colored, many being notably graphitic. Remarkably fine, even cleavage was noted in many places and in some of these the lines followed the configuration of closely compressed folds. Locally a higher degree of alteration has produced phyllites, and again cleavage is but poorly developed or absent, the rock being an indurated shale.

The quartzites occur in massive beds from 10 to 50 feet thick interbedded with the slates and schists. They are most abundant in the northern part of the area, probably being among the lowest members. They are typically developed in the ridge between the main forks of Boulder Creek, in Eureka Dome and vicinity, and in the Little Minook-Quail Creek divide. In each locality heavy beds of hard, vitreous quartzites occur; most of them are dark gray but part are of lighter shades, some being almost milk white. The original quartz grains are plainly evident in many of the specimens and exhibit well-rounded boundaries and regrowth of crystals. In some places thin parallel but widely spaced leaves of muscovite have been developed. The more impure types show a greater degree of metamorphism; they grade in both composition and structure into the schists.

The schists of this age have been produced evidently by the alteration of impure quartzose sedimentary rocks. Some are almost pure quartz and differ from the quartzites only in the development of a schistose structure. However, most of them contain more or less ferruginous matter and secondary femic minerals. Rarely feldspars are included, indicating a derivation from an original arkose. The schists are for the most part light gray, becoming iron stained on weathering.

The assemblage of slates, quartzites, and schists just described is largely if not entirely of Mesozoic age. From one of the quartzites, which are regarded as among its lowest members, a collection of fossil shells was obtained on the Little Minook and Quail Creek divide. These fossils were submitted to T. W. Stanton for determination and the following is quoted from his report:

7241, No. 11 AE5. Little Minook-Quail Creek divide, one-half mile below trail crossing, Rampart quadrangle, Alaska:

Aucella? sp. apparently belonging to the group of *A. crassicollis* Keyserling.

Many fragments of pelecypods, probably Lower Cretaceous or Jurassic.

The collection is far from satisfactory and the determination is given only provisionally. If it is correct, the horizon is either Lower Cretaceous or uppermost Jurassic.

Prindle[1] found Upper Cretaceous fossils in "black, rather massive carbonaceous sandy shales" on Wolverine Mountain. Similar rocks extend southwestward from Wolverine Mountain, and it is probable that the Upper Cretaceous epoch is represented also by some of the dark shales associated with the quartzites and schists. Although the evidence is not as full as might be desired, a considerable range in age seems to be represented in this assemblage. In view of the great thickness of Mesozoic strata in adjacent regions, these rocks may belong entirely to this era—perhaps to only its later epochs.

TERTIARY SHALES, SANDSTONES, AND CONGLOMERATES.

Several small isolated areas of Tertiary sediments occur in the region adjacent to the Yukon. They include clays, shales, sandstones, conglomerates, and thin lignitic seams, and are apparently of fluviatile origin, the coal beds representing vegetal accumulation in the lateral basins of ancient aggrading streams. The beds have suffered considerable deformation, their dips ranging from practically zero to almost vertical. Extensive faulting has also occurred. The Tertiary beds still remaining are probably remnants of deposits that originally extended over the entire region, their preservation being due to a protected position among the older rocks given to them by downfolding or faulting. Owing to the extensive erosion to which the Tertiary strata have been subjected, it is impossible to estimate their original thickness. The present outcrops exhibit beds aggregating hundreds if not thousands of feet.

The exposures along the left bank of the Yukon above the town of Rampart have furnished fossils, both plants and invertebrates, of Eocene age. Concerning the shells W. H. Dall, who examined them, says, "These are *Unio althlios* Meyer, a species first described from the leaf-bearing beds of the Kenai formation of Cook Inlet, Alaska." The plants from this locality were examined by Arthur Hollick, who gave the following report:

Collection 11 AE1. Bluff, left bank of Yukon, 1½ miles above Rampart (Lot No. 6094). This collection consists of four specimens in a friable sandy clay matrix. Apparently only a single species is represented.

Rhus n. sp.

Collection 11 AE2. Bluff, left bank of Yukon, 1½ miles above Rampart, 300 feet higher than 11 AE1 (Lot No. 6095). This collection contains two kinds of matrix.

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[1] Prindle, L. M., The Fairbanks and Rampart quardangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908, pp. 23-24.

One is apparently the same as that of collection 11 AE1; the other is a hard clay ironstone, which may, however, be merely an indurated phase of the former. The following identifications were made:

In sandy clay matrix:
- Ulmus braunii Heer.
- Betula prisca Ettingsh.
- Hicoria magnifica Knowlton.
- Acer arcticum Heer?

In clay ironstone matrix:
- Populus glandulifera Heer.
- Corylus macquarrii (Forbes) Heer.
- Hicoria magnifica Knowlton.
- Grewia crenata (Ung.) Heer.
- Platanus haydenii Newb.?

Age: Eocene.

There can be no doubt that sediments of similar composition and condition in other areas are of approximately the same age as the beds at the locality above Rampart and that all represent the notable period of fluviatile deposition in Eocene time, evidence of which is widespread in Alaska.

QUATERNARY SILTS, SANDS, AND GRAVELS.

Much of the area under discussion is mantled by silt, sand, and gravel deposits of Quaternary age. Although extensive erosion has greatly reduced the amount of these deposits, they still persist as a filling hundreds of feet thick in the lowland areas and occur as remnants up to an elevation of 1,500 feet above the sea, a level to which they evidently at one time filled the older topographic depressions. Plate V, *B*, shows the massive character of the silts at the Palisades of the Yukon.

Deposits of gravel and bowlder usually constitute the base of the series and fine sand and silts make up the greater part of its mass. Some of the bowlders are large, several that measured 5 or 6 feet in their longest dimension being noted. Although most of the bowlders occur in the beds next to bedrock, isolated ones are found well up in the silts, their position indicating an unusual mode of transportation. The silts are fine and light colored and are composed of finely comminuted angular mineral fragments, chiefly quartz, and a little clay. The beds are practically undeformed and only locally are they appreciably consolidated.

Pleistocene mammal remains are plentiful in the lowermost bowlder beds and land shells of species still living in the same region are found in the silts. As silts of like character are a common product of glacial action, it is presumable that those of this series may be of glacial origin. Whether the time of the principal glaciation in this region coincided with that of the Pleistocene ice extensions in lower latitudes is uncertain, and the age of the silts must be regarded

as correspondingly in doubt. The extent to which they have been eroded would indicate a great lapse of time and favor the presumption of early rather than late Quaternary age. The conditions attending the deposition of the silts are discussed more fully in the section on geologic history (p. 27) and special types of the deposits are described in the section on the auriferous gravels (pp. 30–34).

IGNEOUS ROCKS.

The older, metamorphosed igneous rocks have been described in connection with the rest of the metamorphic rocks. Besides these the region contains a number of areas of monzonites and a complex system of dikes composed of rocks that differ greatly in composition.

The monzonites have the forms of batholiths and immense sills, the latter assuming the dip and trend of the principal structure of the region. In the eastern part of the region they occur at the Ramparts of the Yukon, in Roughtop and Hot Springs mountains, and in Elephant Dome. In the Gold Hill district they occupy areas between the heads of Golden and Illinois creeks and north of Little Melozi River. As a rule these areas are manifest topographically, the superior resistance of the monzonite to weathering resulting in prominent rugged mountains.

The typical monzonite is a coarse-grained grayish rock, in hand specimens of which large tabular feldspars, biotite, and a pyroxene can be distinguished. In many specimens border phases show finer grain and a relatively greater abundance of femic minerals. The usual type includes both alkalic and calcic feldspars, augite, biotite, and hornblende, with accessory apatite, titanite, and zircon. In ordinary phases the alkali feldspars predominate and in the more basic differentiations the calcic varieties are more abundant. Feldspars having a wide range in composition are present in most specimens. In one both orthoclase and anorthite are associated with feldspars of intermediate composition. Augite is the most important of the femic minerals. It is pink and pleochroic, probably being titaniferous. Titanite is very abundant in many specimens and should certainly be regarded as an esssential constituent of some. Biotite occurs in small idiomorphic crystals in all the monzonites, and in some of the differentiation phases it is the dominant femic mineral.

Dikes cut the pre-Tertiary rocks in many parts of the region. Some of them are essentially like the monzonites in composition, others are granite and acidic pegmatite. Many pegmatite dikes have a center of practically pure milky quartz containing a few scattered leaves of muscovite and borders of quartz, orthoclase, plagioclase, biotite, aud muscovite, with accessory garnet, tourmaline, and apatite. In many places the border phases of the pegma-

tites are but poorly developed and the dike consists almost entirely of quartz. Numerous quartz veins in the same region may have resulted from a complete transition from dikes to veins.

GEOLOGIC HISTORY.

PRE-TERTIARY TIME.

The legible geologic record of the Rampart and Hot Springs districts begins with the deposition of the oldest of the metamorphic rocks, which probably occurred in Silurian and Devonian time. The history of these periods can not be traced in detail, but certain generalizations may be drawn. That the earlier sediments were deposited beneath the sea is shown by the abundance of limestone and by the fossils that have been found in them. Volcanism began early in the period represented by the older sediments, but was a subordinate factor until near the close of that period. It then prevailed over all other activities and superimposed a great thickness of igneous rock upon the earlier sediments. The earlier volcanic rocks were submarine flows and tuffs and were accompanied by a minor amount of sediments. Later the land was raised or built above sea level, and an exclusively igneous series was formed.

Late Paleozoic and perhaps early Mesozoic time is unrepresented by any lithologic record, unless the slate, sandstone, and conglomerate assemblage is of one of these ages. If it is, the relatively slight alteration of these beds indicates a possible period of diastrophism before their deposition and after that of the older groups.

At some early period the older groups of stratified rocks were intruded by immense granitic masses that have since been deformed and altered with the rocks that they invaded.

As already noted, the rocks of later Mesozoic age—the slate, quartzite, and schist assemblage—are in evident unconformity with the underlying rocks; also they are less altered. The Lower Cretaceous sediments were evidently deformed under heavy cover, and an extended period of erosion ensued before the Upper Cretaceous beds were laid down, for the base of the latter is a conglomerate of quartzite bowlders apparently derived from the Lower Cretaceous quartzites.[1] Both Lower and Upper Cretaceous sedimentation was marine in large part, if not entirely.

After the Upper Cretaceous sedimentation igneous activities were renewed with the intrusion of the monzonites and of various dikes. The area became elevated above sea level, probably with additional folding and faulting of the Cretaceous and older rocks. A long period of erosion followed, during which the Cretaceous beds were removed from large areas, later occupied by younger sediments.

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[1] Prindle, L. M., oral communication.

A. EOCENE BEDS ON LEFT BANK OF THE YUKON 1¼ MILES ABOVE RAMPART.

The beds in this locality are composed chiefly of fine sands and clayey shales.

B. EOCENE BEDS OVERLAIN UNCONFORMABLY BY SILTS IN THE PALISADES OF THE YUKON.

Composed principally of sands and fine conglomerates but contain abundant kaolin, as is shown by their white color

TERTIARY TIME.

To account for the absence of Cretaceous beds beneath the Eocene in certain areas and for the gradation from clays and fine sediments in the lower part of the Eocene to sands and conglomerates higher in the series, a succession of periods differing greatly in erosional activity is required, the differences being due probably to orographic changes.

Between the Cretaceous and the Eocene sedimentation there must have been a long period of active erosion, in which the Cretaceous beds were removed from the areas noted above. Erosion then subsided, probably keeping pace with a general reduction of grades by the streams. Then followed a long period when weathering was the dominant process and when a mantle of the products of rock decay was formed over much of the country.

Next came orographic changes that quickened erosion over certain areas, the materials probably being redeposited at no great distance from their sources. It is reasonable to suppose that the axes along which uplift started these changes were already determined by prior movements and that they probably coincided with the principal divides of the drainage systems. The uplift, then, first affected the headward portions of the streams most strongly. With their energy thus increased the streams easily attacked the surface deposits and delivered large volumes of fine débris to the trunk channels, whose capacity was at first probably little affected by the crustal movements. Deposition in the valleys of the larger streams followed. This resulted in a steepening of grades farther and farther from the seat of uplift. The longer the streams the greater would be the thickness of strata required for the establishment of competent grades to the sea. As aggradation lifted the streams out of their valleys their flood plains coalesced, permitting the continuous deposition of similar materials over wide areas. During this period the interstream areas were probably at times heavily vegetated swamps, in which were accumulated the materials now comprising the lignite beds. Shifting of the streams to new courses as their channels became aggraded above the level of the interstream swamps occurred at intervals, giving in each section an alternation of lignite beds and clastic deposits.

Continued uplift, whether steady or intermittent, permitted the streams, after the removal of the decomposed mantle from the area of strongest uplift, to attack bedrock, and during an intermediate period the products of both decomposition and comminution entered into the Eocene formations, the latter products tending to predominate more and more. (See Pl. VI, *A* and *B*.) In the sequence from the clays and lignites at the base to the sands and conglomerates at the

top of the series is recorded the growth of the mountains and the evolution from the placid streams of the early part of the period to the mountain torrents that at last probably determined the gradient and character of the streams for the entire distance to the sea.

There is some doubt as to the age of certain heavy gravel deposits overlying the beds of known Eocene age south of Tanana River. In some places they are apparently conformable with the Eocene beds, but in others they show evidence of erosional unconformity. These deposits probably record a period in which erosion was greatly stimulated by a marked uplift of the mountain provinces. This uplift might have followed the Eocene deposition either closely or more remotely, for if the intervening period was one of relative stability of the land, the rivers would have reached adjustment and no sedimentary record would have been formed except near the sea. At any rate both the known Eocene beds and the overlying gravels had been laid down before the next notable period began.

After the Tertiary beds were deposited the whole region over which they were spread was affected by diastrophism resulting in a general uplift of the land and the deformation of the beds. General erosion was renewed by these movements, and the later Tertiary history of the region is a record of the stages of land degradation. There is strong evidence in many parts of interior Alaska to show that the late Tertiary uplift was not continuous, but halted in at least one stage long enough for the reduction of large areas approximately to base-level. This stage was recorded in the Yukon Plateau, a peneplain which was later dissected and whose remnants have been widely recognized. In this stage the Tertiary beds were completely removed from large areas but remained wherever they were flexed or faulted below the level of the peneplain. After the period of base-leveling degradational agencies were again brought into play by further elevation of the land and the areas of less resistant Tertiary beds became the object of selective erosion. In this stage, principally by the removal of Tertiary beds, the areas of relative depression in post-Eocene time received topographic expression in valleys and lowlands, outlining the orographic features that were to persist to the present day.

QUATERNARY TIME.

Erosion subsequent to the elevation of the Yukon Plateau had progressed for a long time prior to the beginning of the Quaternary period and had produced the well-developed system of valleys of a mature topography. Interstream areas were small, many of the lower ones being in the form of sharp ridges. Either the land was standing at a higher elevation or the streams had lower gradients

than those of to-day, for in many depressions that then existed the present streams have their courses laid over a great thickness of Quaternary filling.

During earlier Quaternary time an important group of sediments was laid down, rock-cut terraces were formed on the sides of the pre-Quaternary valleys, interstream ridges at certain elevations were horizontally truncated, and the Yukon, assuming a course at variance with the pre-Quaternary depressions, excavated its canyon-like valley through the Ramparts.

The Quaternary sediments filled the older valleys in the vicinity of the Ramparts to a height which is now about 1,500 feet above sea level. This altitude also closely approximates that of the top of the Ramparts, the higher rock-cut terraces, and the truncated ridges. It is apparent that the level of these features must have been reached at the time when the Yukon assumed its present course at the Ramparts by a body of water in which the silts were deposited and whose shore lines are marked by rock-cut terraces and truncated ridges. The elevation of the Yukon at the Ramparts during the period of their development exercised a controlling influence on the erosion in the upstream portion of its basin. Many terraces below the highest may represent the activities of the river or of ponded waters during periods of relatively slow lowering of the Ramparts barrier.

In the Tanana basin Quaternary silts and gravels were deposited and rock-cut terraces were developed, but neither stand at as great an elevation as the corresponding features in the Yukon basin, the highest being about 1,200 feet above sea level. The lower terraces apparently represent the beach erosion of a body of water whose surface was rising by successive stages, not falling, for the deposits of each successive terrace overlap those of the terraces below it.

The Quaternary inundation was followed by the withdrawal of the waters and the establishment of the drainage systems in their present forms. Later erosion has left only remnants of the earlier Quaternary deposits, having redeposited or completely removed from the region their larger part.

The area here under consideration is unglaciated itself, but to the influence of glaciation in adjacent parts of Alaska are probably due the special activities noted as having affected it during the earlier part of the Quaternary age.

Many of the auriferous gravels lie beneath thick deposits of gravel and silt and probably represent concentrations incident to the erosion of the pre-Quaternary valleys. Others developed on the terraces are probably early Quaternary concentrations. Certain streams have developed courses across Quaternary terrace deposits and their gravels represent a still later period of concentration, which is still in progress.

ECONOMIC GEOLOGY.

GENERAL FEATURES.

Gold is the only mineral whose occurrence in the Rampart quadrangle has proved to be of economic importance. It has been mined profitably in both the Rampart and Hot Springs districts, and is known to occur at a number of other localities. The known distribution of auriferous gravels is shown on Plate VII.

Tin occurs with the gold in the placers of Sullivan Creek, and small quantities have been recovered incidentally to the gold mining. So far, however, no serious attempt has been made to recover any large part of the tin ore and no profitable disposal has been made of that saved.

Lignitic coal occurs in the Eocene beds near Rampart, but no seams thick enough to be mined profitably have been found.

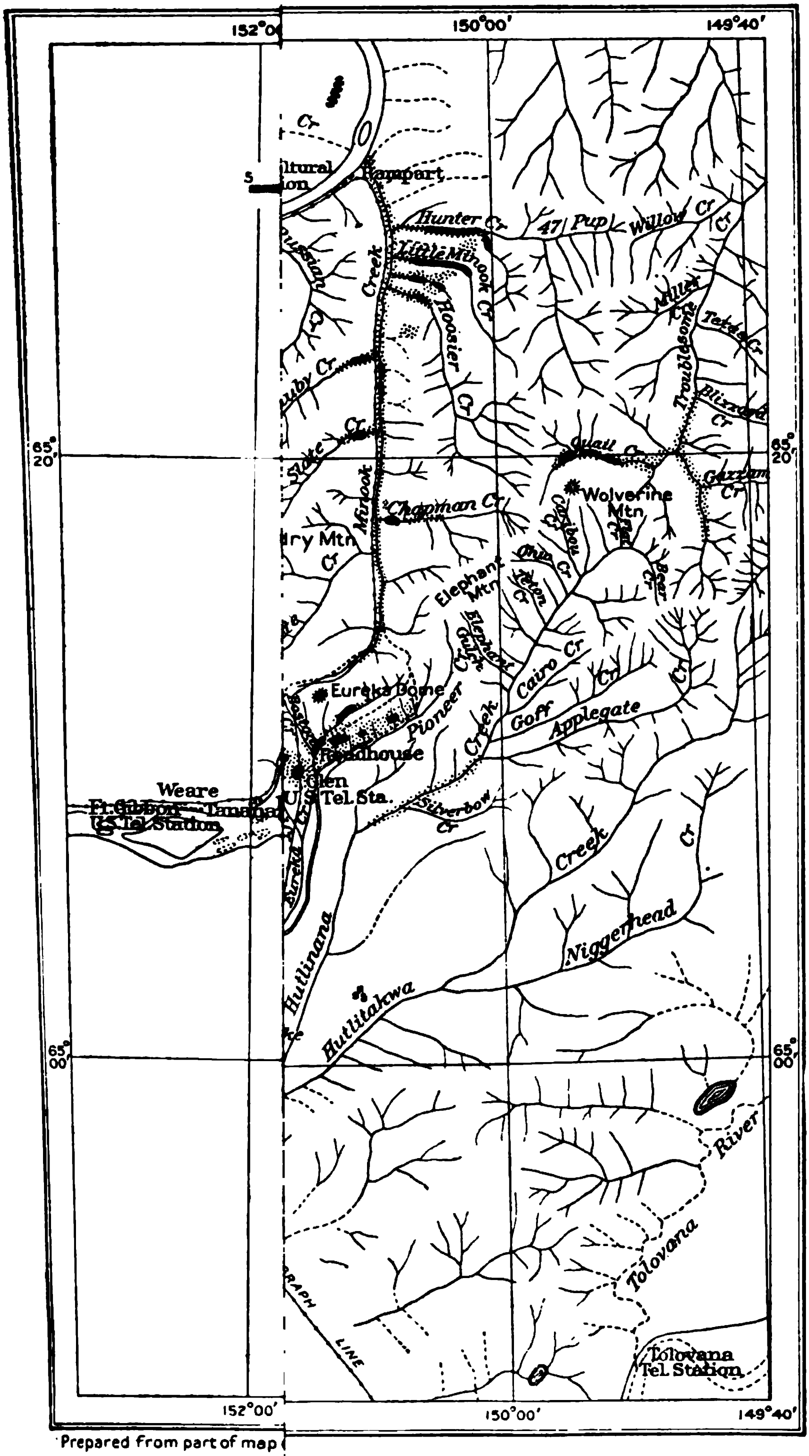
GOLD.

HISTORY OF DEVELOPMENT.

Placer gold was discovered in the Rampart district probably as early as 1893. The first discoveries were made on Minook Creek and its tributaries, and since 1896 systematic mining has been carried on in this district, the first claim worked being on Little Minook Creek. (See Pl. VIII, *B*, p. 34.) Later, as the area being prospected increased, placers were located and mines developed on the tributaries of Baker Creek along the northern border of the flats, and still later on Sullivan Creek and neighboring streams tributary to Patterson Creek.

Prospecting on the tributaries of the Yukon and Tanana west of the productive areas has revealed the presence of gold in a number of localities, as shown on Plate IV (in pocket). Although much ground is held on some of these streams, especially in the Gold Hill district, the presence of gold in commercial quantities has not been demonstrated. In the Gold Hill district this may be due in great part to the facts that very little besides annual assessment work is being done and that what is done is largely futile.

The scene of greatest activity in mining in the Rampart and Hot Springs districts has shifted to the south as successive discoveries have been made. The Rampart district yielded its greatest output in 1906 and 1907. The placers along the north margin of Baker Flats reached their maximum production about the same time but have not fallen off so rapidly as the Rampart district. The Patterson Creek locality has steadily increased its production since operations were begun, the season of 1911 recording the largest output in its history.



Prepared from part of map

ER GOLD.

Gold and silver produced in Rampart district.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1896 to 1903, inclusive	29,799.00	$616,000	4,440	$2,664
1904	4,353.75	90,000	649	376
1905	3,870.00	80,000	576	351
1906	5,805.00	120,000	865	588
1907	6,046.87	125,000	901	595
1908	3,628.13	75,000	540	286
1909	4,837.50	100,000	721	375
1910	2,080.12	43,000	310	167
1911	1,548.00	32,000	231	125
Total	61,968.37	1,281,000	9,233	5,527

Gold and silver produced in Hot Springs district.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1902 and 1903	12,717.79	$262,900	1,818	$964
1904	7,038.56	145,500	1,007	584
1905	5,806.00	120,000	831	507
1906	8,707.50	180,000	1,245	843
1907	8,465.63	175,000	1,210	798
1908	7,256.25	150,000	1,038	550
1909	15,721.87	325,000	2,248	1,169
1910	15,721.88	325,000	2,248	1,169
1911	37,974.37	785,000	5,430	2,932
Total	119,408.85	2,468,400	17,075	9,516

SOURCE OF THE GOLD.

The distribution of the gold in the Rampart and Hot Springs districts is definitely related to the metamorphic rocks. The bedrock in the Rampart district is mainly greenstone, which is accompanied by a variety of slates, cherts, and impure limestones, all more or less altered. The Hot Springs district, from American Creek to the Baker Creek placers, lies within the slate, quartzite, and schist area, and the placer ground of Quail Creek, which heads against Little Minook Creek, is a continuation of the same area.

Quartz veins are so plentifully distributed in the older rocks of the entire region that a greater abundance in the areas containing the placers can hardly be asserted. Although as a rule the quartz veins are barren of visible mineralization, there is some evidence that in the placer districts they are gold bearing. On Little Minook Creek a vein 6 feet wide is said to yield gold on being crushed and panned. In the Sullivan Creek placers the richer ground is thought by the operators to be marked by an unusual abundance of quartz veins. In both districts nuggets composed partly of quartz are common. In the Gold Hill district is a quartz vein known to be auriferous,

but an unsuccessful attempt has proved that it is not of sufficient extent or richness to be mined profitably.

Although these facts indicate that much of the placer gold comes from quartz veins, another source is suggested for at least a part of it in the Hot Springs district. Nuggets from What Cheer Bar, near Glen, contain fragments of black slate. In the tailings of one of the Sullivan Creek mines was found a piece of quartzite having tiny stringers of gold along its cleavage planes. It would appear that on these creeks the gold was deposited in the available spaces in the country rock, wholly without gangue minerals. The formations comprising the country rock in all the placer districts contain members that are very rich in carbonaceous material. Carbon is thought to influence the precipitation of gold under certain conditions, and it seems possible that the distribution of gold in the region may be in some degree related to that of the carbonaceous beds.

Still another source of gold may be the hematite deposits in the neighborhood of the monzonite areas near Hot Springs and Roughtop Mountain. Brecciated zones of the country rock ranging from a few inches to several feet in width have received deposits of hematite. Samples taken from these deposits, both in the Roughtop Mountain locality and near Hot Springs, are said to yield steady assay returns of several dollars a ton in gold. Although such an occurrence of gold is unusual, it is far from impossible, but further sampling, including entire crosscuts of minable bodies of the ore, will be required to establish the economic value of the hematite.

AURIFEROUS GRAVELS.

The auriferous gravels of the Rampart and Hot Springs districts, considered in their relation to modern topography, are of two types—stream gravels, forming the beds and flood plains of modern streams, and terrace gravels, situated above the present valley floors. Some deposits of the latter type cover benches that undoubtedly were formed by the present streams; others do not clearly indicate this origin.

The stream gravels have furnished the greater part of the gold output of the Rampart district, the operations on all the creeks except Hunter being confined to these gravels. On Hunter Creek only a small part of the gold produced has come from this source. The stream gravels of the district are shallow, as a rule; on Minook they range in thickness from a few feet to 15 or 20 feet, and on the smaller streams the range is even less, the usual thickness being from 6 to 8 feet. The gravels lie under a cover of muck and silt, which generally thickens toward the sides of the valley. It appears that the valleys were at one time more or less completely filled with

silt, a large part of which has been removed. Where the removal has been most complete, near the courses of the streams, open-cut mining is employed, but nearer the valley walls, where the overburden is very heavy, drifting is necessary.

In the Hot Springs district a large part of the gold taken from the streams tributary to Baker Creek has come from the stream gravels. The deposits of this type are similar to those of the Rampart district except that generally they are overlain by a much thinner overburden of silt or muck. The stream gravels of the Patterson Creek group carry gold in small quantities, but are nowhere rich enough to be mined profitably.

Terrace gravels occur in both the Rampart and Hot Springs districts. In the Rampart district well-defined benches occur on Minook and Hunter creeks. Those on Hunter Creek lie along the valley walls and may represent stages in the down cutting of the stream. The lowest bench on Hunter Creek, lying as a rule only 15 or 20 feet above the stream, has been the principal source of the Hunter Creek gold. The bedrock floor of this bench is irregular, in some places sloping downward away from the stream, toward the valley wall. The actual surface of the bench slopes upward toward the margin of the valley, especially in the vicinity of lateral streams. The upper part of this bench deposit seems to be composed largely of materials delivered to the main valley by its tributaries in the form of alluvial fans of varying steepness. The deposits of the lower terrace of Hunter Creek are minable by open cuts along their streamward margins, being made up, as a rule, of 3 to 6 feet of gravel with an overburden of a few feet of muck. The notable thickening of the overburden toward the margins of the valley limits the width of ground to which open-cut mining is applicable.

Ill-defined remnants of terraces occur at various elevations along the sides of Minook Valley, but only the lower bench, which resembles that of Hunter Creek, has been productive.

The ridges between the eastern tributaries of Minook Creek are peculiarly flat-topped and rise eastward in a succession of broad steps standing from 600 to 800 feet above the level of Minook Creek. Some carry gravel deposits that have proved, locally at least, to be gold bearing. Prospecting has revealed deposits of various depths, the thickest being more than 100 feet deep. Their materials in the main consist of more or less worn fragments of the local country rock, yellow clays or silts, and scattered quartzite bowlders, many of great size, which are foreign to the immediate neighborhood. Only very low contents of gold have been reported from these deposits, and their elevated position, even if they should prove to contain larger amounts of gold, would render their exploitation very difficult.

In the Hot Springs district bench gravels have been productive on most of the gold-bearing streams tributary to Baker Creek, and in practically all the Patterson Creek placers the deposits have no evident relation to the present streams.

The peculiar type of bench deposits characteristic of the Hot Springs district is illustrated by What Cheer Bar. This deposit skirts the point between Eureka and Pioneer creeks, lying at a level about 250 feet vertically above the latter stream and 2,000 feet above it up the side of the valley. A space 2,000 feet long and from 150 to 200 feet wide has been mined and the resulting cut reveals the general character of the deposit. What Cheer Bar is a flattened space on a gently sloping valley side, which formerly bore auriferous gravels ranging in depth from 3 to 10 feet. The gravels range in size from fine material up to bowlders several feet in diameter. The bench has no perceptible grade the long way, but crosswise toward Pioneer Creek, it slopes at a grade which was found suitable for the sluice boxes but which is less than the general slope of the hillside. At the uphill side of the bench the bedrock rises at a steeper angle than elsewhere, coming nearly to the surface, and then flattens to the general slope of the hillside. Most of the bowlders found in the deposit are quartzite, but some are conglomerate. Rocks of these types occur in place in the basin of Pioneer Creek and perhaps in the hill on which the bench is developed. Other benches that carry a little gold occur on the hillside above What Cheer Bar, and farther up the valley of Pioneer Creek, on the same hillside, similar deposits have been productive.

A heavy deposit of gravel occurring along the north side of Baker flats west of Eureka Creek is apparently unrelated in origin to the present streams, which flow transversely across it. Although in general this deposit has proved to be of too low a tenor to be worked, it carries some gold and probably has been the source of much of the gold found in the gravels of the streams where they cross it.

In the Patterson Creek locality shallow gravels are worked by open cuts on Quartz Creek and Tofty Gulch. The deposit on Quartz Creek, known as Homestake Bar, is about a quarter of a mile from the creek, on a slightly sloping hillside. It consists of 3 or 4 feet of gravel overlain by 3 feet of yellow silt. The gravels are little worn except in a thickness of about 1 foot next to bedrock. The entire hillside is covered with deposits similar to those being worked except that they carry less gold. The workable deposit extends horizontally along the hillside and no surface indications suggest its extent. However, the bedrock slopes toward the creek at a lower angle than the surface of the ground, and at the uphill margin it rises more sharply, forming a so-called rim. The rim seems to mark the limit of the

ıe ground is worked by ground sluicing and with

a considerable open cut has been made on a bench ›out 1,000 feet from Sullivan Creek. The deposit 5 feet of gravel covered by several feet of yellow silt Large bowlders were very common in the top layers ı some were found in the lower part of the silt. The ;ained a great many remnants of trees, which added the difficulty and expense of mining. In working top layers of muck and silt were ground-sluiced off, ɕ employed to break up the tangle of wood débris in ıich the gravels were carried to the sluice boxes with a

›lacers of Sullivan Creek and those of Cache Creek lie 30 to 75 feet below the surface. They are worked by ɕhinery is employed to hoist the gravel to the surface. s of the gravel deposits ranges from 10 to 35 feet, the ɜpth below the surface being made up by an overburden ɜ reported that 90 feet of silt was penetrated in sinking an l prospecting shaft at a place between Cache and Sullivan

rels include some well-worn materials but are made up ıngular fragments of the country rock. In fact, it is often ı distinguish the surface of the bedrock, so closely does it he fragmental deposits. One prospect hole was abandoned eached a lens of this material, but when deeper holes near by ıled rich gravels the shaft was sunk through the lens, and eached the true bedrock workable gravels were found.

ıore worn materials are usually of the most resistant types, ritreous quartzite being common. Many bowlders of this ɔ large to handle are encountered in all the drifts; in some lrifts all the vertical space is taken up by a single bowlder. ɜr, as these bowlders are generally more or less isolated they ı serious difficulty to mining.

; of the bedrock surface is much weathered, being brecciated ırrying gold to a depth of a foot or more. The configuration bedrock surface in all the deeper mines is that of a succession benches, which rise one after another toward the higher ground. ichest gravels are commonly found near the uphill margin of the ıes.

e auriferous gravels of American Creek are somewhat similar to ıench gravels of the Patterson Creek locality. It is reported that ɜ of the later discoveries have been made on bench ground than ne stream gravels. The depths range from 10 to 20 feet. The

gravels are worked by drifting and so far no steam machinery has been used in hoisting.

On Grant Creek and some of its tributaries and on Illinois Creek, in the Gold Mountain district, good prospects are reported, but so far, the presence of valuable deposits has not been demonstrated. Prospecting is seriously hindered by the great depths to the gravels in much of the district and by live water where they are unfrozen. On Illinois Creek a hole is said to have been sunk 133 feet and then abandoned on account of live water, so that it did not reach bedrock. This shaft passed through several beds containing fine gold.

On Grant Creek the results have been much the same, live water having caused the abandonment of holes when they had been sunk from 30 to 135 feet. The only holes sunk to bedrock on Grant Creek are about 2½ miles above its mouth and have a depth of about 30 feet. A few holes on Lynx Creek, the principal eastern tributary of Grant Creek, have reached bedrock at a depth of about 20 feet, discovering on bedrock a foot of gravel said to yield at the rate of $10 or $12 a yard. After a small amount of drifting had been done the works were abandoned. On American Gulch, a small tributary of Grant Creek near its head, the gravels are said to yield the best prospects found in the region, some estimates putting the values as high as $1 a square foot of bedrock. The gravels are 10 to 12 feet deep and are not frozen. The construction of a bedrock drain, which has been unsuccessfully attempted, would probably afford more definite knowledge of the deposit.

WATER SUPPLY.

With the exception of Minook Creek and two of its tributaries, Hunter and Hoosier creeks, the streams of the Rampart and Hot Springs districts furnish a very scanty supply of water for mining. Hunter Creek usually has a discharge sufficient for two 3-inch nozzles under a 150-foot head, and in time of freshets, of course, its discharge is much greater. Its recorded minimum flow[1] is 3.7 second-feet, or about 150 miner's inches, and its maximum is 27 second-feet, or more than 1,000 miner's inches. Hoosier Creek is of very nearly the same size. Little Minook Creek carries less than a sluicehead during much of the drier part of the season.

Eureka Creek at its mouth has a discharge similar to that of Hunter Creek. About half of this is contributed by Pioneer Creek and about a fourth by the main head of Eureka Creek above Pioneer Creek. None of the tributaries of Patterson Creek at the locality of the mines furnishes sufficient water for constant sluicing during much of the summer, and pumping is practiced at most of the plants.

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[1] Ellsworth, C. E., Water-supply investigations, Yukon-Tanana region, Alaska: Water-Supply Paper U. S. Geol. Survey No. 228, 1909, p. 68.

A. SPLASH DAM ON LITTLE MINOOK CREEK.

B. LITTLE MINOOK CREEK, SEEN FROM IDAHO BAR.

MINING IN 1911.

RAMPART DISTRICT.

General conditions.—Active mining in the Rampart district during 1911 was limited to Hunter and Little Minook creeks, of the Big Minook basin, and to Quail Creek, a tributary of Troublesome Creek. Gravels that were generally of lower tenor than those mined in former years were encountered and the difficulties of mining were greater, owing to an increase of the overburden as the valley walls were approached and to the obstruction caused by tailings of former operations.

Hunter Creek.—On Hunter Creek two hydraulic plants were operated during the summer of 1911. A steam hoist was installed on Dawson Creek, a tributary of Hunter Creek, but owing to an accident was abandoned for the summer. A single claim was worked to a small extent by pick and shovel. About 12 men were employed on four claims during a part of the summer.

Little Minook Creek.—On Little Minook Creek five claims were worked to some extent during the year. The operations included winter drifting on two claims and during the summer the use of two splash dams, employing about seven men. (See Pl. VIII, *A*.)

Quail Creek.—Quail Creek was not visited by the writer. It was learned, however, from the miners near Rampart that four splash dams were operated most of the summer, employing from 8 to 12 men at different times.

HOT SPRINGS DISTRICT.

General conditions.—The year 1911 witnessed a marked decrease in mining operations in the part of the Hot Springs district tributary to Baker Creek, contrasting with an increased activity in the Patterson Creek camp. In the former locality Thanksgiving, Omega, Pioneer, Eureka, and Hutlinana creeks were active. In the latter mining was in progress on Sullivan, Cache, Quartz, and American creeks.

Thanksgiving Creek.—In the early summer about 20 men were sluicing and shoveling in on Thanksgiving Creek. Later in the season operations were at a standstill, owing to lack of water.

Omega Creek.—A single claim is reported to have been worked on Omega Creek in 1911; it was being drifted, the gravel being hoisted by hand. The ground was about 16 feet deep and the results were said to be satisfactory.

Eureka Creek.—A steam scraper was employed in open-cut work on Eureka Creek near the mouth of Boston Creek. On the upper part of Eureka Creek a claim was worked by means of a splash dam. Eight or ten men were employed on this creek.

Pioneer Creek.—Four men were employed in sluicing on the bench ground of What Cheer Bar, on the right bank of Pioneer Creek, a little above its mouth. Two or three claims were being worked higher up on Pioneer Creek but were not visited. About 15 men were said to be employed in the summer workings.

Hutlinana Creek.—Four men operated two splash-dam outfits on the upper part of Hutlinana Creek during the summer. Nothing definite was learned of their success.

Sullivan Creek.—The greatest activity in the whole region was in the Sullivan Creek locality. Six steam hoists, employing about 150 men, were in operation most of the summer. In depth to bedrock the claims range from 30 to 70 feet. Most of the overburden is yellow silt, the rest being gravel and black muck.

The gold is usually in the lowest 2 or 3 feet of gravel and in the shattered bedrock. According to the reports of operators the tenor of the gravels, expressed in terms of the area of bedrock uncovered, ran from about 50 cents to more than $20 a square foot, and selected pans from the pay streak of the richest claim carried $10 to $15 in gold. The tenor of the gravels actually removed ranged from about $3.50 a yard to very much higher figures.

The costs of mining vary with conditions on the different claims and the methods employed. Many of the plants were compelled to pump water for sluicing, which adds considerably to the expense for fuel and cost of upkeep. The lowest estimate of the cost of operation was 35 cents a square foot of bedrock, which is equivalent to about $2.50 a yard of gravel. On some claims the costs were probably more than double this amount.

In the summer valuable gravels were discovered on a claim adjacent to those being worked, and further prospecting will very likely disclose a still wider distribution of pay gravel in this locality.

Cache Creek.—Three steam hoists were operated on Cache Creek in the early part of the summer, but at the time of the writer's visit two had shut down. The third plant was employing about 25 men but had only a small amount of ground remaining to be worked. The general mining conditions are similar to those on Sullivan Creek, the pay gravel lying at a depth of 50 feet and the water supply requiring the use of the pump for sluicing.

Quartz Creek.—A single plant was operating on Quartz Creek. The ground is on a bench on the right bank of the creek and is shallow, permitting the use of open-cut methods. A large area had been stripped by groundsluicing off a covering of tundra and about 3 feet of muck, and two men were shoveling in. The gravel deposit is from 1 to 2 feet deep and consists mostly of angular, little-worn material except in the part very near bedrock. Although the entire waters

of the creek were diverted into the ditch, the supply was sufficient for sluicing less than half the time. There is said to be much ground along this bench which could be profitably worked if sufficient water could be had for hydraulic mining, but which can not be exploited by the more expensive hand methods.

American Creek.—A discovery of placer gold on American Creek, a small stream flowing into Fish Lake about 15 miles west of the Patterson Creek mines, was reported early in 1911. Active prospecting during the summer revealed pay gravel on at least four claims, from one of which a considerable production is reported. A hand windlass was used in hoisting the pay dirt, the ground on most of the claims being only 12 or 15 feet deep. From 30 to 50 men were on the creek during most of the summer, and preparation was being made for extensive work in both prospecting and mining during the winter.

TIN.

Smoothly rounded pebbles of cassiterite, the oxide of tin, occur with the gold in the Sullivan Creek placers. The neighboring placers on Cache and Quartz creeks are barren of this mineral, so that the area in which it occurs is small, being less than a mile in its longest direction. The tinstone or stream tin, as it is commonly called, varies in amount with the gold, the placers commonly being rich or lean in both minerals. In the richest spots as much as half a pound of tin to the pan is reported, which at the present price of the ore would give the gravels a value, not allowing for costs of mining or transportation, of $18 to $20 a yard, according to assay.

Gravels that contain as little as 9 pounds of cassiterite to the yard are being mined profitably in the York region, Alaska. There can be little doubt that a great part of the gravels mined on Sullivan Creek carry as high a content of tin as this and that some may run much higher. However, on account of the inconvenience that the tin ore occasions in the extraction of gold, the tin is regarded as a nuisance by the miners of the district rather than as a possibly valuable product.

The bedrock source of the tin has been the subject of a great deal of speculation, and considerable effort has been made to locate it. This effort, however, has been expended in the region about Roughtop Mountain rather than in the neighborhood of the placers, under the impression that only an area of igneous rock could furnish the mineral. Although in its typical occurrence in bedrock tin ore is evidently closely related to some igneous rock from which the tin-bearing solutions probably emanated, cassiterite may occur also in quartz veins and small dikes at some distance from any large igneous mass. There is a strong likelihood that the tin of these placers has not been brought a great distance to its present position. Apparently it has

been derived from the veins and dikes of the country rock that has been eroded from the area in which the tin-bearing placers are found. Bedrock prospecting in the vicinity of the mines is difficult, owing to the thick covering of gravel and silt. Nevertheless, it would be desirable to make a closer scrutiny of the bedrock exposed in the mines and in the neighboring hills, especially of the quartz veins and micaceous dikes, which may possibly be tin bearing. Should any angular and little-worn cassiterite be found in the gravels, it would be good evidence of a bedrock deposit near at hand.

That the quartz veins of the Sullivan Creek area are probably the source of the tin as well as of a large part of the gold is indicated by the structure of the ore, which is a recemented breccia. The fragments of the breccia are vein quartz. The cementing material is principally cassiterite. Blue and brown tourmaline and small amounts of fluorite also fill spaces between the quartz fragments in some of the specimens. From this structure it is inferred that the quartz veins were originally formed without the other minerals, along the joint planes of the country rock. Subsequently dynamic stresses, possibly due to the injection of an igneous mass underneath the region, caused movement along these planes and the brecciation of the quartz veins. This igneous mass might also have furnished the tin-bearing emanations from which the ores were derived.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. $1.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4–9.

The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, 1908, pp. 30–53. 45 cents.

*The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21–62. 50 cents.

The mining industry in 1909, by A. H. Brooks. In Bulletin 442, 1910, pp. 20–46.

The mining industry in 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 21–42.

*The mining industry in 1911, by A. H. Brooks. In Bulletin 520, 1912, pp. 19–44. 50 cents.

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*Railway routes from the Pacific seaboard to Fairbanks, Alaska, by A. H. Brooks. In Bulletin 520, 1912, pp. 45–88. 50 cents.

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*Tin resources of Alaska, by Frank L. Hess. In Bulletin 520, 1912, pp. 89–92. 50 cents.

*Administrative report, by A. H. Brooks. In Bulletin 259, 1905, pp. 13–17. 15 cents.

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*Administrative report, by A. H. Brooks. In Bulletin 379, 1909, pp. 5–20. 50 cents.

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Report on progress of public land surveys during 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 15–20.

*Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin 259, 1905, pp. 128–139. 15 cents.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.

Markets for Alaska coal, by G. C. Martin. In Bulletin 284, 1906, pp. 18–29.

The Alaska coal fields, by G. C. Martin. In Bulletin 314, 1907, pp. 40–46.

Alaska coal and its utilization, by A. H. Brooks. In Bulletin 442, 1910, pp. 47–100.

*The possible use of peat fuel in Alaska, by C. A. Davis. In Bulletin 379, 1909, pp. 63–66. 50 cents.

Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 443, 1910, 89 pp.
Geology and mineral resources of the Nizina district, Alaska, by F. H. Moffit and S. R. Capps. Bulletin 448, 1911, 111 pp.
Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts, by F. H. Moffit; including geologic and topographic reconnaissance maps. Bulletin 498, 1912, 82 pp.
The upper Susitna and Chistochina districts, by F. H. Moffit. In Bulletin 480, 1911, p. 127.
*The Taral and Bremner districts, by F. H. Moffit. In Bulletin 520, 1912, pp. 93–104. 50 cents.
*The Chitina district, by F. H. Moffit. In Bulletin 520, 1912, pp. 105–107. 50 cents.
*Gold deposits near Valdez, by A. H. Brooks. In Bulletin 520, 1912, pp. 108–130. 50 cents.
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The Hanagita-Bremner region, Alaska, by F. H. Moffit. Bulletin —. (In preparation.)

Topographic maps.

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Copper, Nabesna, and Chisana rivers, headwaters of; scale, 1:250,000; by D. C. Witherspoon. Contained in Professional Paper 41. Not issued separately.
Controller Bay region; No. 601 A; scale, 1:62,500; by E. G. Hamilton. Price 35 cents a copy or $21 per hundred.
Headwater regions of Gulkana and Susitna rivers; scale, 1:250,000; by D. C. Witherspoon and C. E. Giffin. Contained in Bulletin 498. Not published separately.

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The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin 250, 1905, 64 pp.
*Coal resources of southwestern Alaska, by R. W. Stone. In Bulletin 259, 1905, pp. 151–171. 15 cents.
*Gold placers of Turnagain Arm, Cook Inlet, by F. H. Moffit. In Bulletin 259, 1905, pp. 90–99. 15 cents.
*Mineral resources of the Kenai Peninsula: Gold fields of the Turnagain Arm region, by F. H. Moffit, pp. 1–52; Coal fields of the Kachemak Bay region, by R. W. Stone, pp. 53–73. Bulletin 277, 1906, 80 pp. 25 cents.
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*A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. Bulletin 289, 1906, 36 pp.
Reconnaissance in the Matanuska and Talkeetna basins, by Sidney Paige and Adolph Knopf. In Bulletin 314, 1907, pp. 104–125.
Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska, by Sidney Paige and Adolph Knopf. Bulletin 327, 1907, 71 pp.
*Notes on geology and mineral prospects in the vicinity of Seward, Kenai Peninsula, by U. S. Grant. In Bulletin 379, 1909, pp. 98–107. 50 cents.
Preliminary report on the mineral resources of the southern part of Kenai Peninsula, by U. S. Grant and D. F. Higgins. In Bulletin 442, 1910, pp. 166–178.
Outline of the geology and mineral resources of the Iliamna and Clark lakes region, by G. C. Martin and F. J. Katz. In Bulletin 442, 1910, pp. 179–200.
Gold placers of the Mulchatna, by F. J. Katz. In Bulletin 442, 1910, pp. 201–202.
The Mount McKinley region, by A. H. Brooks, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle. Professional Paper 70, 1911, 234 pp.
A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp.
Geology and coal fields of the lower Matanuska Valley, Alaska, by G. C. Martin and F. J. Katz; including detailed geologic and topographic maps. Bulletin 500, 1912, 98 pp.
*Gold deposits of the Seward-Sunrise region, Kenai Peninsula, by B. L. Johnson. In Bulletin 520, 1912, pp. 131–173. 50 cents.

The occurrence of iron ore near Haines, by Adolph Knopf. In Bulletin 442, 1910, pp. 144–146.
A water-power reconnaissance in southeastern Alaska, by J. C. Hoyt. In Bulletin 442, 1910, pp. 147–157.
Geology and mineral resources of the Berners Bay region, Alaska, by Adolph Knopf. Bulletin 446, 1911, 58 pp.
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The Eagle River region, southeastern Alaska, by Adolph Knopf, including detailed geologic and topographic maps. Bulletin 502, 1912, 61 pp.
The Sitka mining district, Alaska, by Adolph Knopf. Bulletin 504, 1912, 32 pp.
The earthquakes at Yakutat Bay, Alaska, in September, 1899, by R. S. Tarr and Lawrence Martin. Professional Paper 69, 1912, 135 pp.

Topographic maps.

Juneau special map; scale, 1: 62,500; by W. J. Peters. For sale at 10 cents each or $3 for 50.
Berners Bay special map; scale, 1 : 62,500; by R. B. Oliver. For sale at 10 cents each or $3 for 50.
Topographic map of the Juneau gold belt, Alaska. Contained in *Bulletin 287, Plate XXXVI, 1906. 75 cents. Not issued separately.
Kasaan Peninsula, Prince of Wales Island. No. 520–A; scale, 1 : 62,500; by R. H. Sargent, D. C. Witherspoon, and J. W. Bagley. For sale at 10 cents each or $3 for 50.
Copper Mountain and vicinity, Prince of Wales Island, scale, 1: 62,500; by R. H. Sargent. For sale at 10 cents each or $3 for 50.

CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

*The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall. Professional Paper 15, 1903, 71 pp. Contains map of Prince William Sound and Copper River region; scale, 12 miles=1 inch. 30 cents.
*Bering River coal field, by G. C. Martin. In Bulletin 259, 1905, pp. 140–150. 15 cents.
*Cape Yaktag placers, by G. C. Martin In Bulletin 259, 1905, pp. 88–89. 15 cents.
*Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin 259, 1905, pp. 128–139. 15 cents. (Abstract from Bulletin 250.)
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*Notes on copper prospects of Prince William Sound, by F. H. Moffit. In Bulletin 345, 1908, pp. 176–178. 45 cents.
*Mineral resources of the Kotsina and Chitina valleys, Copper River region, by F. H. Moffit and A. G. Maddren. In Bulletin 345, 1908, pp. 127–175. 45 cents.
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*Copper mining and prospecting on Prince William Sound, by U. S. Grant and D. F. Higgins, jr. In Bulletin 379, 1909, pp. 87–96. 50 cents.
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*Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp. 25 cents.
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Placer mining in the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 230-245.
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A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp.
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*Gold placers of the Yentna district, by S. R. Capps. In Bulletin 520, 1912, pp. 174–200. 50 cents.

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*Kenai Peninsula, northern portion; scale, 1:250,000; by E. G. Hamilton. Contained in Bulletin 277. 25 cents. Not published separately.

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*Gold mine on Unalaska Island, by A. J. Collier. In Bulletin 259, 1905, pp. 102–103. 15 cents.

*Gold deposits of the Shumagin Islands, by G. C. Martin. In Bulletin 259, 1905. pp. 100–101. 15 cents.

*Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin 259, 1905, pp. 128–139. 15 cents. (Abstract from Bulletin 250.)

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*Mineral resources of southwestern Alaska, by W. W. Atwood. In Bulletin 379, 1909, pp. 108–152. 50 cents.

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A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz; including geologic and topographic reconnaissance maps. Bulletin 485, 1912, 138 pp.

Topographic maps.

The Balboa-Herendeen Bay and Unga Island region; scale, 1:250,000; by H. M. Eakin. Contained in Bulletin 467. Not issued separately.

The Iliamna region; scale, 1:250,000; by D. C. Witherspoon and C. E. Giffin. Contained in Bulletin 485. Not issued separately.

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*The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, by L. M. Prindle. Bulletin 251, 1905, 89 pp. 35 cents.

Yukon placer fields, by L. M. Prindle. In Bulletin 284, 1906, pp. 109–131.

Reconnaissance from Circle to Fort Hamlin, by R. W. Stone. In Bulletin 284, 1906, pp. 128–131.

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*The Yukon-Tanana region, Alaska; description of the Fairbanks and Rampart quadrangles, by L. M. Prindle, F. L. Hess, and C. C. Covert. Bulletin 337, 1908, 102 pp. 25 cents.

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*The Fortymile gold-placer district, by L. M. Prindle. In Bulletin 345, 1908, pp. 187–197. 45 cents.

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Mining in Seward Peninsula, by F. F. Henshaw. In Bulletin 442, 1910, pp. 353-371.
Water-supply investigations in Seward Peninsula in 1909, by F. F. Henshaw. In Bulletin 442, 1910, pp. 372-418.
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Geology of the Nome and Grand Central quadrangles, Alaska, by F. H. Moffit. Bulletin 533, 1913, 140 pp.
Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology, by P. S. Smith, and a description of methods of placer mining, by Alfred H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp.

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*Fairbanks and Birch Creek districts, reconnaissance maps of; scale, 1: 250,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. 35 cents. Not issued separately.

Circle quadrangle, Yukon-Tanana region; scale, 1: 250,000; by D. C. Witherspoon. Price 50 cents a copy. Also contained in Bulletin 295.

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*A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900, by A. H. Brooks, G. B. Richardson, and A. J. Collier. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 180 pp. 50 cents.

*A reconnaissance in the Norton Bay region, Alaska, in 1900, by W. C. Mendenhall. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 38 pp. 50 cents.

*A reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. Professional Paper 2, 1902, 70 pp. 30 cents.

*The tin deposits of the York region, Alaska, by A. J. Collier. Bulletin 229, 1904, 61 pp. 15 cents.

*Recent developments of Alaskan tin deposits, by A. J. Collier. In Bulletin 259, 1905, pp. 120–127. 15 cents.

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The Kougarok region, by A. H. Brooks. In Bulletin 314, 1907, pp. 164–181.

*Water supply of Nome region, Seward Peninsula, Alaska, 1906, by J. C. Hoyt and F. F. Henshaw. Water-Supply Paper 196, 1907, 52 pp. 15 cents.

Water supply of the Nome region, Seward Peninsula, 1906, by J. C. Hoyt and F. F. Henshaw. In Bulletin 314, 1907, pp. 182–186.

The Nome region, by F. H. Moffit. In Bulletin 314, 1907, pp. 126–145.

Gold fields of the Solomon and Niukluk river basins, by P. S. Smith. In Bulletin 314, 1907, pp. 146–156.

Geology and mineral resources of Iron Creek, by P. S. Smith. In Bulletin 314, 1907, pp. 157–163.

The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin 328, 1908, 343 pp.

*Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin 345, 1908, pp. 206–250. 45 cents.

*The Seward Peninsula tin deposits, by Adolph Knopf. In Bulletin 345, 1908, pp. 251-267. 45 cents.

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*Water supply of the Nome and Kougarok regions, Seward Peninsula, in 1906–7, by F. F. Henshaw. In Bulletin 345, 1908, pp. 272–285. 45 cents.

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Geology of the Seward Peninsula tin deposits, by Adolph Knopf. Bulletin 358, 1908, 72 pp.

*Recent developments in southern Seward Peninsula, by P. S. Smith. In Bulletin 379, 1909, pp. 267–301. 50 cents.

*The Iron Creek region, by P. S. Smith. In Bulletin 379, 1909, pp. 302–354. 50 cents.

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*Water-supply investigations in Seward Peninsula in 1908, by F. F. Henshaw. In Bulletin 379, 1909, pp. 370–401. 50 cents.

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